VOL. XV, NO. 6 DECEMBER, 1922

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

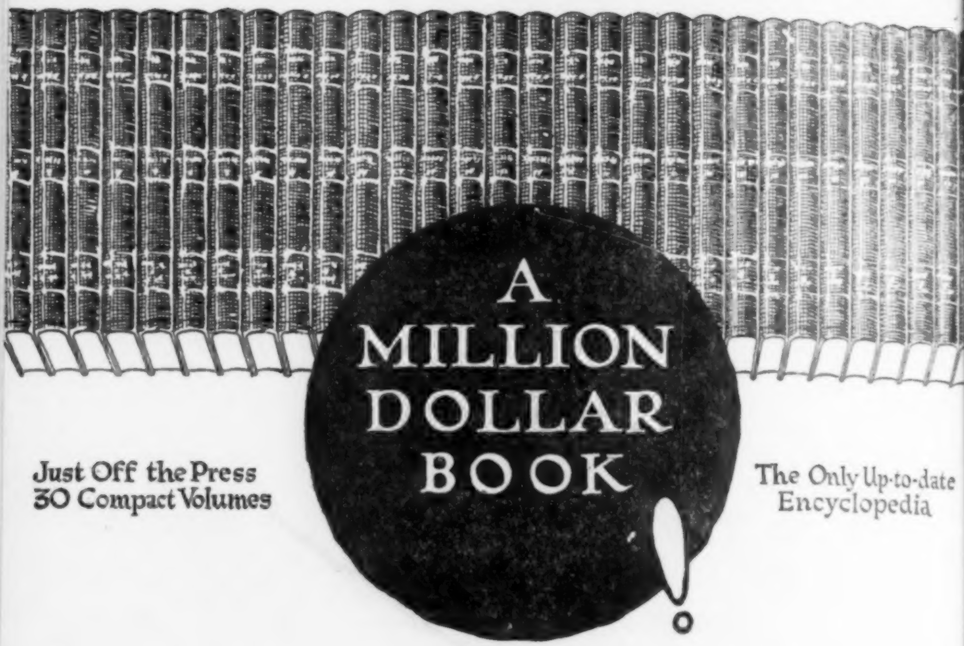
PUBLICATION OFFICE: 11 LIBERTY ST., UTICA, N. Y.

EDITORIAL AND BUSINESS OFFICE: GARRISON, N. Y.

New York Office: The Grand Central Terminal

Single Number, 50 Cents. Yearly Subscription, $5.00

Entered as second-class matter November 9, 1921, at the Post Office at Utica, N. Y., under the Act of March 3, 1879.



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THE SCIENTIFIC MONTHLY

DECEMBER, 1922

THE VEGETATION OF AUSTRALIA AND NEW ZEALAND

By Professor D. H. CAMPBELL
STANFORD UNIVERSITY

THOSE parts of the world which for one reason or another are completely isolated show very plainly the effects of this isolation upon the animals and plants which inhabit them. The degree of specialization in these organisms is to a certain extent an index of the length of time the region has been shut off. A comparison of these organisms with those of other regions may throw light upon such problems as the changes in the distribution of land and water upon the earth's surface in the course of ages, and thus be of great interest to the geologist and geographer as well as to the biologist.

If we compare the lands of the northern hemisphere, as they now exist, with the principal land masses of the southern hemisphere, we find the former to be very much more extensive than the latter. In the north there is a marked preponderance of land in the polar and subpolar regions, which merge into the temperate regions in both the American and Eurasian continents. In the southern hemisphere there is an extensive almost absolutely barren polar continent, but the regions corresponding to the subarctic land masses of the north are entirely occupied by water; and the south temperate regions are completely separated from the antarctic continent by a wide stretch of sea.

Moreover, the temperate regions of Australasia, South Africa and South America are widely separated from each other by the Atlantic, Pacific and Indian oceans. In extent the temperate regions of the south are much less than those of the northern hemisphere. As might be expected, this condition of things is accompanied by a much greater diversity in the temperate floras of the southern hemisphere than is the case in northern latitudes. This perhaps reaches its maximum in the Australasian region, the completely isolated Australian continent and the islands of New Zea-

land having extremely specialized floras which are of very great interest to the student of plant geography.

While Australia and New Zealand are usually grouped together geographically as "Australasia," they differ much from each other in their vegetation, although having more or less in common. New Zealand is separated from Australia by over a thousand miles of sea, and many of the most characteristic Australian types are quite absent, and others only very sparingly represented. Owing to its very much greater size and range of climate, Australia, as might be expected, possesses a much more extensive flora than the relatively small islands of New Zealand.

The completely isolated continent of Australia is almost exactly the size of the continental United States exclusive of Alaska. The Australian climate, however, is very different. The northern portion of Australia is within the tropics, the tip of York Peninsula being only 11 degrees from the equator, while the southernmost part of the continent scarcely touches the fortieth degree of latitude. The adjacent island of Tasmania extends about three degrees further south. The climate is therefore much warmer on the whole than that of the United States or Europe, the coolest regions in the south having a climate comparable to that of California or the Mediterranean. At the north a true tropical climate prevails.

The topography of Australia is much less varied than that of the United States. There are no mountains comparable to our great western ranges, and there is a marked dearth of large rivers and lakes. The principal mountain masses are close to the eastern coast, a succession of mountain ranges and highlands extending from the York Peninsula to eastern Victoria and Tasmania. In Queensland there are some definite mountain ranges, but for the most part the high land is a plateau sloping gradually westward, with more or less definite escarpments toward the east. These escarpments sometimes exhibit abrupt gorges cut by the streams. These are well shown in the Blue Mountains west of Sydney. The highest point in Australia is Mt. Kosciusko, 7,300 feet, situated in New South Wales near the Victoria border.

This highland region and the adjacent coastal areas have for the most part a good rainfall, but there are no large rivers. The heaviest rainfall is in the coastal region of North Queensland where at certain stations it may exceed two hundred inches annually and averages one hundred and fifty.

Inland, however, the rainfall diminishes rapidly, and a third of the continent is said to have ten inches or less annually and another third less than twenty. This means that two thirds of the area of Australia must be classed as desert or semiarid, and

much of it unsuited to agriculture, although vast areas are more or less adapted to grazing, which at present in much of the commonwealth is the most important industry. There is a more or less marked wet and dry season in most of Australia, as on our own Pacific coast. In the south most of the rain falls during the winter months, May to September; in the north the heaviest rains fall in the summer. June is the wettest month in the south, January in the north.

Northern Australia, lying entirely within the tropics, has for the most part a genuinely tropical climate, hot and humid in the coastal districts. In the more elevated regions of the plateau, however, there may be sharp frost during the winter months, June to August. In August of last year I observed bananas and other tender plants cut down by frost at an elevation of 2,000 to 3,000 feet, in latitude 17°. On the coast, however, frost is quite unknown, and the forest shows a genuine tropical luxuriance.

The wettest region in Australia is in northeast Queensland, on the coast, about latitude 17°. In this region a short range of precipitous mountains rises directly from the coast to a height of over 5,000 feet, the highest land in the state. At the foot of this range, the precipitation is very heavy. One place, Babinda, which I visited in August, 1921, had already registered over two hundred inches for the year, and it rained almost incessantly during my stay.

The low swampy forest about Babinda was almost impenetrable, the trees loaded down with creepers of various kinds, among which the rattan palms were only too conspicuous. Throughout the eastern tropics the thickets of rattans are a great hindrance to progress in the forest, as their tough, horribly spiny twining stems make absolutely impenetrable tangles, natural barbed-wire barriers. Climbing Aroids and species of Vitis and Piper are also abundant as well as various other lianas.

In these wet lowland jungles, the palms reach their fullest development, forming a conspicuous and beautiful feature of the vegetation. One of the commonest and most attractive species is *Archontophoenix Cunninghamiana*, often cultivated under the name *Seaforthia elegans*, and one of the most beautiful of all palms, with its smooth slender trunk and crown of graceful feathery leaves. No feature of the Australian vegetation is more beautiful than the groves of these lovely palms.

Screw-pines (Pandanus) abound in this region and there are also a number of species of Cycads. Australia is especially rich in these ancient plants. The most widespread genus is Macrozamia, of which there are several species, the genus having representatives in all the states. The two other Australian genera, Cycas and

FIG. 1. TROPICAL RAIN-FOREST, NORTH QUEENSLAND

Bowenia, are confined to tropical Queensland. The latter genus, peculiar to Australia, differs much in appearance from any living Cycads, in its solitary bi-pinnate leaves, rather suggesting a bracken fern.

In the dryer parts of the Queensland coast the rain-forest is replaced by a more or less mixed forest, composed in part of Eucalyptus, and in part of tropical rain-forest types, like Ficus. A forest of this type may be seen occupying the sandy soil in the neighborhood of Cairns, the principal port of North Queensland.

A feature of the coast in this district is the mangrove formation along the shore and the banks of the streams flowing into the sea. Several genera are represented, the most important being the widespread Rhizophora and Avicennia.

Some interesting ferns were noted in this region, the most striking being a gigantic Angiopteris which was seen in several places in the vicinity of Babinda.

Immediately back of the coast the land rises rapidly to a plateau reaching an extreme elevation of about 4,000 feet, but averaging 2,000 to 3,000 feet over most of its extent.

This table-land has an ample rainfall, and on the better soils develops a fine forest which yields extremely valuable timber. Much of the timber has been destroyed, but there are still some remnants which are accessible, and these are really magnificent examples of tropical forest growth. This tropical rain-forest is known in Queensland by the very inappropriate name of "Scrub" and is confined to the rich basaltic and alluvial soils.

The trees of this forest are mainly of Malayan affinity, and are tall with lofty straight trunks yielding a large amount of fine timber. Some of them, especially the Kauri (*Agathis Palmerstoni*) and "Red Cedar" (*Cedrela toona*) reach a very large size. The latter was formerly abundant and sometimes attained a diameter of upwards of ten feet. It has been largely exterminated, but an occasional fine specimen may still be seen, and the same is true of the Kauri.

Belonging to the same family (Meliaceae) as the cedar are several species of Flindersia, which are locally known as "hickory," "maple," "beech," and other woods not in the least related to them. Other characteristic trees are Elaeocarpus, (Tiliaceae), *Aleurites Moluccana*, widespread throughout Polynesia; Sideroxylon (Sapotaceae), Eugenia (Myrtaceae) and others. The characteristic Australian family Proteaceae is represented in the rain-forest by several species of Grevillea, Stenocarpus, Macadamia and other genera. *Grevillea robusta* of southern Queensland is often grown in California as an ornamental tree.

This upland forest has much finer trees than the lowland forest

FIG. 2. TRUNK OF GIANT FIG, NEAR YUNGABURRA, NORTH QUEENSLAND

near the coast, but the palms and some other tropical types are almost entirely absent, and the development of the epiphytes and lianas is not so marked, although these are by no means absent. Many of the large trees, as is so common in rain-forests everywhere, show a conspicuous development of buttresses at the base of the trunk.

The giants of the forest are species of Ficus, the size of which is amazing. As in most tropical lands the genus is well represented in northern Australia, some species extending as far south as Sydney. Like so many other species of Ficus, these giant Queensland figs begin life as epiphytes, the descending roots finally coalescing more or less completely, and strangling the host tree. The descending roots are produced in great numbers and in one tree that was seen, the huge conical trunk formed by the united roots was said to measure 120 feet in circumference at the ground, and the enormous spreading crown was in proportion.

While the predominant forest on the plateau is "scrub," there are large areas occupied almost exclusively by open Eucalyptus forest. This Eucalyptus forest is the dominant type of vegetation over much of Australia, but in the region in question is restricted to areas of sandy soil. The line between the "scrub" and the Eucalyptus forest is often very sharply marked, and is probably determined by the difference in the soil.

In southern Queensland, in the neighborhood of Brisbane, the Eucalyptus forest predominates, though there are also areas occupied by "scrub," but many of the strictly tropical species of North Queensland are absent.

Probably the most striking tree of South Queensland is the "Bunya" (*Araucaria Bidwilli*) a coniferous tree confined to a relatively small area in this region. It reaches a large size, and is valuable for its timber. The big seeds were much prized as food by the aboriginals. This handsome tree is frequently cultivated in California, where it seems very much at home. A second species, *A. Cunninghamii,* is much more widely diffused, and was seen in extensive pure stands on some of the islands off the coast of Queensland.

An analysis of the constituents of the scrub vegetation of Queensland and New South Wales shows that it is largely made up of genera widespread through the Indo-Malayan region, or closely related to these, and may very properly be considered a part of the great Malayan flora. Such types as the figs, palms, screw-pines, Araceae, many epiphytic ferns and orchids are characteristic of the whole Indo-Malayan region; and as it is evident that northeast Australia was connected at no very distant period with the great island of New Guinea, it is pretty certain that this portion of the Australian flora is derived from the north.

FIG. 3. BUNYA PINES (ARAUCARIA BIDWILLI), BOTANICAL GARDENS, BRISBANE

This Malayan flora is best developed in northeast Queensland, some of the forms like the pitcher plants (Nepenthes) and certain genera of palms (Borassus, Areca, Caryota, etc.) being confined to the York Peninsula, Australia's northernmost extension, which is separated from New Guinea by only about 100 miles of water.

Some of the Malayan types, like Cedrela and two or three palms, and a considerable number of others, extend southward to the borders of Victoria; but this vegetation is confined to regions of ample rainfall and rich soils, and the number of these Malayan types diminishes rapidly toward the south.

While the scrub vegetation is made up for the most part of the Malayan types there are a number of genera probably of Australian origin. Such are the fine trees Tristanea (allied to Eucalyptus) the silky oak (*Grevillea robusta*), Stenocarpus and Macadamia of the Proteaceae, a family which reaches its maximum development in Australia.

The luxuriant scrub-forest disappears as one proceeds inland, and with the diminishing precipitation is replaced by the open Eucalyptus forest. Still further inland in Queensland are extensive open grass lands or prairies which afford pasturage to great herds of cattle.[1]

To the south of Queensland is the state of New South Wales, the first colony to be established in Australia. The coastal region is a continuation of that of southern Queensland and has much the same vegetation as the latter, but the Malayan elements diminish toward the south, where there is an increasing proportion of true Australian types such as Eucalyptus and Acacia. The scrub, however, retains a decidedly tropical aspect, with tall palms and tree-ferns in abundance.

Much the greater part of the state, however, is far too dry for such forest growth, and is occupied by a very different type of vegetation. This is almost purely of Australian origin and is more or less decidedly xerophytic in character. The predominant trees are various species of Eucalyptus forming open forests with the sandy soil between occupied by a great variety of low shrubs, often with extremely showy flowers. Herbaceous plants are less conspicuous, although there are coarse grasses and a good many perennial plants growing from tubers, corms or bulbs. The Myrtaceae, so abundant in Australia, have numerous species of Leptospermum and Melaleuca; the Leguminosae include many species of Acacias, "Wattle" in the vernacular, and a bewildering array of showy Papilionaceae; several beautiful species of Boronia

[1] Maiden, J. H.: "Australian Vegetation," p. 207. *Federal Handbook for Australia*, Melbourne, 1914.

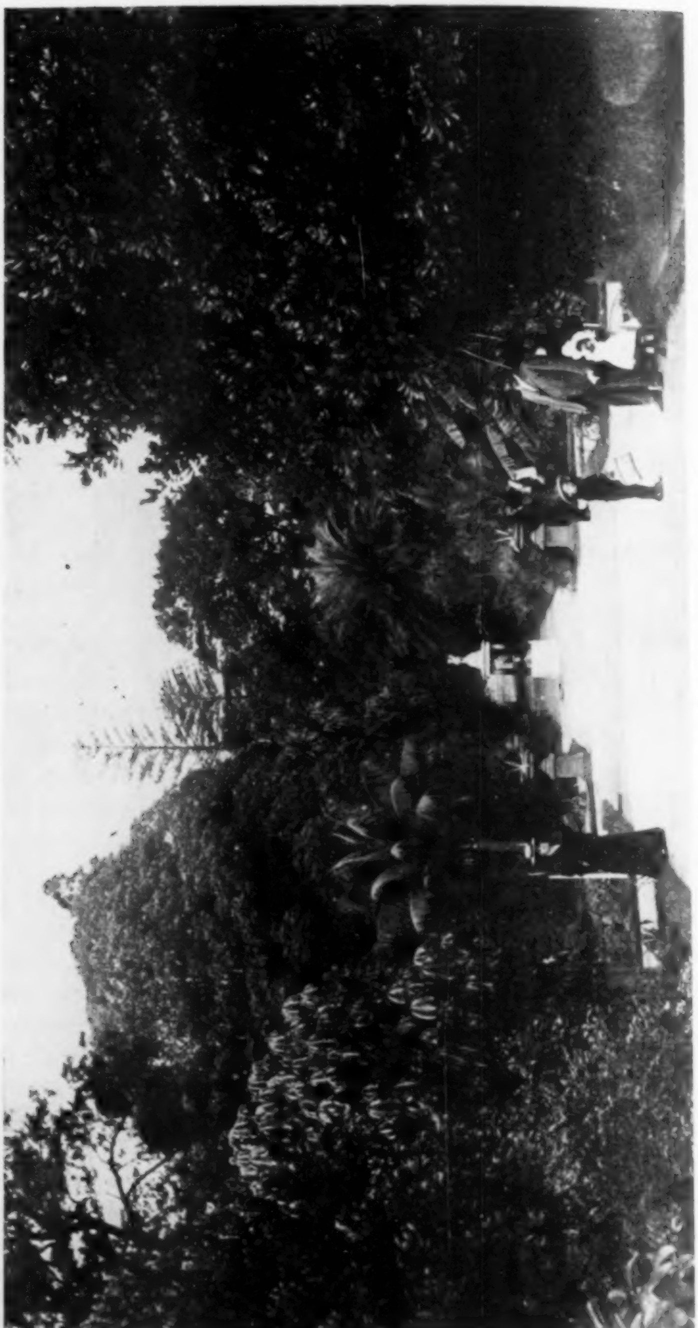


Fig. 4. BOTANICAL GARDENS, SYDNEY

and Eriostemon (Rutaceae) and many other striking and unfamiliar flowers abound. The Proteaceae, as everywhere in Australia, are much in evidence, the most abundant being species of Hakea, Banksia and Grevillea. To this family belongs one of the most gorgeous of Australian flowers, the "Waratah," whose magnificent scarlet flowers are the pride of New South Wales. Another very striking plant peculiar to New South Wales may be mentioned—the giant torch lily (*Doryanthes excelsa*), bearing an enormous cluster of great scarlet lilies on a stout stalk ten or fifteen feet in height.

Victoria, the smallest state, occupies the southeast corner of Australia, and is about the size of Kansas. It is the best cultivated, and apparently the most prosperous state of the commonwealth. Much of the state has a climate adapted to the cultivation of most crops of the north temperate zone, and better suited to the North European settlers than the hotter parts of Australia. Its smaller size and more uniform rainfall result in a lesser variety of vegetation than in the larger states; but in the mountain districts of the east are found the tallest trees in Australia, close rivals of the California redwood. These forests of giant gums with their heavy undergrowth of tree-ferns and other luxuriant vegetation are among the finest in the world. Where the forest has been cleared, the land is some of the best in the commonwealth.

The distinctive Australian flora is seen at its best in West Australia. This immense state occupies the entire western third of the continent, and is almost completely separated from the eastern states by extensive deserts, and is itself very largely a region of extremely low rainfall. There is, however, a small region occupying the extreme southwest portion, which has a fairly heavy rainfall, and this district possesses a flora which for variety and beauty has scarcely a rival anywhere in the world.

Travelling overland from Victoria one traverses the rather uninteresting state of South Australia, and then proceeds by the recently completed line over the desert to West Australia.

This desert is not unlike certain parts of our own western arid regions, often suggesting parts of Nevada or Arizona. While extensive tracts show only sparse salt-bush (Atriplex, Kochia), much resembling the sage-brush deserts of Nevada or Utah, more often there is a fairly heavy growth of small trees, interspersed with low shrubs, and sometimes bunch grasses and a few flowering herbaceous plants.

The commonest trees are, as usual, species of Eucalyptus, but other abundant trees are species of Casuarina, whose thin leafless twigs simulate the needles of a pine. These curious trees, while not exclusively Australian, being also found in the Malayan region, reach their maximum development in Australia.

FIG. 5. GIANT GUM-FOREST, VICTORIA

The commonest shrubs are species of Acacia and dwarf Eucalyptus, the former at the time of my visit being covered with masses of golden bloom, which enlivened the prevailing dull gray green tints of the foliage. A species of sandal-wood grows in this region as well as a number of other interesting trees and shrubs.

Comparatively few showy flowers are seen, aside from the Acacias. Occasionally masses of pretty pink and white everlastings are encountered, and a gorgeous scarlet pea (*Clianthus Dampieri*).

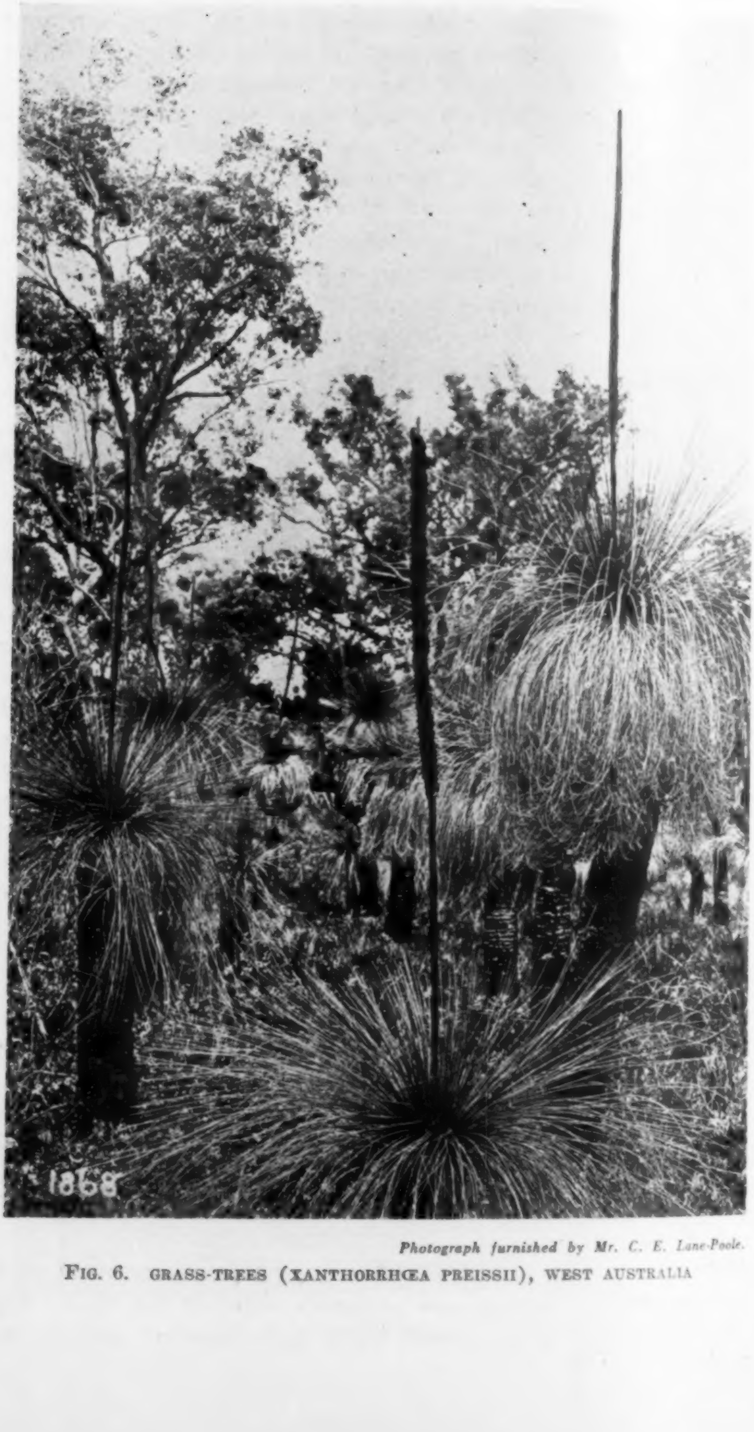
As the western coast is approached the country becomes somewhat less arid, and presently there appears along the railway line an increasing profusion of beautiful flowers, until before Perth, the terminus of the railway, is reached, the train travels through a veritable garden of brilliant bloom. The beauty and variety of this wonderful floral display must be seen to be appreciated. While some of the flowers, such as the great variety of pea-shaped blossoms, suggest familiar northern types, many are entirely strange with little suggestion of relationship with any northern genera.

Whole families, quite unknown to this northern botanist, are richly represented. Thus the Goodeniaceae, a characteristic Australian family, has a large number of extremely showy species of Goodenia (yellow), Dampiera and Leschenaultia (blue), one of the latter, *L. formosa*, of a wonderful blue that would put to shame an Alpine gentian.

Ground orchids are very abundant, some of them of great beauty. They belong largely to special Australasian genera, Caladenia, Diuris, Thelymitra and other quite unfamiliar ones. The little sundews of northern bogs are here represented by an extraordinary assemblage of species, some slender, half climbing plants four to five feet high with flowers the size of small roses. Pink Boronias and Tetratheca (Tremandraceae), yellow Hibberties (Dilleniaceae) are a few of the many beautiful novelties among the lower growing species; while Banksias, Hakeas and Grevilleas of the Proteaceae; Leptospermum, Callistemon, and Melaleuca of the Myrtaceae, are the predominant larger growths.

Of the Monocolyledons, aside from the orchids already referred to, and various grasses and sedges, there are a number of attractive species. The Iridaceae are represented by species of Patersonia with pretty blue or purple flowers. Of the lily-family are several species of Thysonotus, with delicate fringed petals, and Burchardia, whose umbels of pretty white blossoms suggest an Allium or the Californian Brodiæa.

Peculiar, if not beautiful, were the extraordinary grass-trees, or "black-boys," as they are commonly called in the West. The larger species develop a stout trunk and somewhat resemble an



Photograph furnished by Mr. C. E. Lane-Poole.

FIG. 6. GRASS-TREES (XANTHORRHŒA PREISSII), WEST AUSTRALIA

arborescent Yucca, but the leaves, which are very numerous, are slender and more or less drooping. The insignificant flowers are borne on a club-like spike, sometimes six or eight feet high. The plants are said to flower especially freely after a recent fire, and a grove of these strange plants with hundreds of these upright flower-spikes is one of the most striking botanical sights of Australia. A related genus, Kingia, is confined to western Australia.

Among the most extraordinary flowers of West Australia are the "Kangaroo Paws" (Anigozanthus). These flowers are of the most bizarre coloring—bright green and scarlet, yellow and black, red and yellow, or pure green. The genus is unknown outside West Australia. The only Gymnosperm noted was a Cycad, *Macrozamia Fraseri*. This is very common, and is regarded as a serious pest, as animals are often poisoned by eating the young foliage in time of drought. Throughout the less arid parts of West Australia, this wonderful floral display may be seen in the spring, August to November. It perhaps reaches its culmination in the Albany district on the south coast. Certainly the variety of flowers near Albany surpasses anything the writer has seen in any part of the world.

I was unable to visit the Island of Tasmania, which differs much in its topography and climate from the mainland of Australia, and is much more like New Zealand in these respects. It is very mountainous and in many parts, especially in the west, the rainfall is extremely heavy. This heavy precipitation and relatively low temperature resemble the climatic conditions in the south island of New Zealand, and there is a considerable degree of resemblance in the vegetation of the two regions.

In common with New Zealand there is an important element of the flora closely related to, or even identical with, South American species. Some of these "Fuegian" plants are found also in the parts of the adjacent state of Victoria and also as Alpines in the mountains further north.

The most striking of these are the evergreen beeches (*Nothofagus spp.*) which are a notable constituent of the flora of southern Chile and also of New Zealand. These are the sole representatives of the Cupuliferae (oaks, beeches, etc.) found in Australasia.

The visitor to Australia is immediately impressed by the predominance of the Eucalyptus forest, and indeed this is the commonest tree genus. While much of this open forest is extremely monotonous and unattractive, it must be remembered that among the more than two hundred species there are some of the stateliest and most beautiful trees known anywhere. The great Karri forests of West Australia and the giant gum forests of Victoria, as well as some of the Eucalypts from the rich mountain forests

of New South Wales and Queensland, are some of the most magnificent the writer has ever seen.

In the spring, when the new foliage is developing, many species show beautiful golden and ruddy tints in the young leaves that are in strong contrast with the gray-green of the adult foliage of most species. In the arid regions of the interior there are dwarf species shrubs of moderate size remarkably resistant to drought.

The flowers of some species of Eucalyptus are very beautiful and produced in great profusion. As in so many Myrtaceae the numerous stamens form the showy part of the flower and are pure white, pink or scarlet in color. The splendid *E. ficifolia* with brilliant scarlet stamens is a favorite ornamental tree in parts of California.

The Myrtaceae, aside from Eucalyptus, are very largely developed in Australia, being second in number of species in the Australian flora,[2] more than eight hundred having been described. Allied to Eucalyptus are Tristanea, Angophora and Syncarpia, all fine trees of large size.

In the moister and warmer areas of the coast are members of the widespread genera Myrtus, Eugenia and Barringtonia, the latter entirely tropical in its habitat, a very beautiful tree with large glossy leaves and big white flowers. The genus is common throughout the Malayan region and the southern islands of Polynesia.

More characteristically Australian and represented by many species are the genera Leptospermum and Melaleuca, very widely distributed and often forming extensive thickets. Some of the Melaleucas are small trees; the Leptospermums are as a rule shrubs of medium size. The flowers are usually white and produced in great profusion, so that some species are very attractive when in flower and prized as garden ornaments. Other characteristic Myrtaceae are the showy red "bottle-brushes"—species of Callistemon and the pretty fringed flowers of the West Australian Verticordias.

First in number of species in the Australian flora is the great family of Leguminosae, with over one thousand species. Acacia leads with upwards of four hundred, ranging from tiny shrubs a few inches in height to large trees. The Acacias are popularly known as "wattle," and in the spring the profusion of golden bloom of many species makes them very conspicuous. Some of these Australian wattles are common in cultivation and often called "Mimosa." The majority of the Australian Acacias are of the "phyllodineous" type, *i. e.*, the feathery leaf-lamina is sup-

[2] Maiden, *loc. cit.*, p. 166.

pressed and the flattened leaf-stalk, or "phyllode," looks like a simple lanceolate leaf.

The section Papilionaceae, or Pea family, contributes a host of showy flowers to the floral show. Nearly all of these exhibit very brilliant colors, pink, crimson, scarlet, orange, yellow, blue and purple, and the flowers are borne in profusion. Many belong to strictly Australian genera—*e. g.*, Chorizema, Gastrolobium, Jacksonia, etc., and comparatively few are in cultivation.

The third family, in point of numbers, the Proteaceae, has not a single representative in the United States, and is almost entirely absent from the northern hemisphere. About two thirds of the species belong in Australia, and South Africa is next in number of species. The Proteaceae are mostly shrubs of moderate size, but a considerable number are arborescent, becoming forest trees. Of these trees, the most important are the species of Grevillea Banksia, Stenocarpus, Macadamia and several others peculiar to the rain-forests of Queensland. The handsome *Grevillea robusta* is a fine tree frequently seen in California, and a few other species of Grevillea and Hakea are less commonly seen in gardens; but many fine species, well worth cultivation, are still to be seen only in the wild. Grevillea is the largest genus and is widespread in Australia. The flowers are often very showy, pink, scarlet or yellow. Hakea, next in number of species, has as a rule rather inconspicuous flowers.

Few Australian trees are more peculiar in habit than some of the Banksias, whose stiff serrate leaves and huge oblong heads of yellow flowers are most peculiar and striking. The great majority of the Proteaceae are xerophytic, but a few inhabit the scrubs of New South Wales and Queensland. Perhaps the finest flowers among the Proteaceae belong to the "Waratah" of New South Wales, previously referred to. Other important families, nearly or quite confined to Australia, are the Tremandraceae, Goodeniaceae, Candolleaceae and Casuarinaceae.

Reference has already been made to some of the Australian Gymnosperms, which are extremely interesting. The Cycads have already been mentioned, as well as the Araucarias and Kauri of Queensland. The coniferous types of the northern hemisphere are absent, the nearest relation being the genus Catlitris, which is related to the cypresses.

The Yew family or Taxaceae, however, is remarkably developed in the southern hemisphere and has a number of extremely interesting forms in Australia and especially Tasmania. Podocarpus, of which a small number of species occur in the warmer parts of the northern hemisphere, is the most important Australasian genus,

and comprises a number of large and valuable trees, as well as some smaller ones. Species occur in all the states.

Certain genera, absent from the mainland, are found in Tasmania and New Zealand. Such genera are Phyllocladus and Dacrydium, as well as several others.

Ferns and their relatives are scarce or entirely wanting in a very large part of Australia, owing to the prevalence of arid and semi-arid conditions unsuited to these moisture-loving plants. There are, however, regions where they abound and are an important feature of the vegetation. The ubiquitous bracken-fern (*Pteridium aquilinum*) often covers large tracts of open land, as in northern regions; and in the moist gullies of the Blue Mountains of New South Wales and the forests of Victoria or in the rain-forests of the north there is a rich assortment of Pteridophytes, including some very fine treeferns, interesting Lycopods and the curious Psilotum and Tmesipteris, whose life-histories, which long baffled the botanist, have at last been revealed through the labors of Lawson and Holloway.

In the rain-forests are many epiphytic species, of which the extraordinary stag-horn ferns (Platycerium) are the most conspicuous; but there are also a good many of the beautiful and delicate filmy ferns (Hymenophyllaceae).

New Zealand

New Zealand comprises two large islands of about equal size and several adjacent ones of very much smaller dimensions. The northernmost point of the North Island is about 34° south latitude, and the South Island extends to south latitude 47°. The total area of the islands is about 100,000 square miles.

New Zealand presents a marked contrast to Australia, both in its topography and climate. Its relatively small area results in a climate of distinctly insular character, with very much less range of temperature and precipitation than is the case in continental Australia. Owing to its higher latitude, the climate as a whole is rather cool, but severe cold is rare in the lowlands. It is comparable with the climate of Britain, but especially in the North Island is considerably warmer. Owing to the proximity of the sea, there is less difference between North and South than might be expected. Thus between Auckland in the North Island and Invercargill, about ten degrees further south, there is less than ten degrees difference in the average temperature.

For the most part rain is abundant and well distributed, and much of the country shows a luxuriant growth of forest. There are certain regions, however, notably the Canterbury Plain of the South Island, which have a relatively scanty rainfall and are

mostly destitute of trees. These grass-covered plains may be compared to the prairies of the mid-west of the United States.

The topography of New Zealand is for the most part exceedingly rugged, with much higher mountains than those of Australia. In the North Island are extensive volcanic formations, some of which are still active. In the Rotorua district, familiar to tourists, are numerous hot springs and geysers much like those of the Yellowstone and in addition there are active volcanic craters.

In the neighborhood of Auckland are a number of very perfect extinct cones, and on the west coast is Mt. Egmont, over eight thousand feet high. To the south lies the Wellington district, extremely rugged in character. The harbor of Wellington, surrounded by steep mountains, opens into Cook's Strait, separating the North and South Islands.

The South Island shows less extensive evidences of volcanic activity than the North Island. It is distinguished by the lofty snow-clad range of the Southern Alps near the west coast, culminating in the majestic Mount Cook, over twelve thousand feet high, snow covered for most of its height and with extensive glaciers reaching nearly to its base. The southwest coast is indented by numerous fiords, which are said to present a magnificent spectacle.

The Southern Alps exercise a great influence on the climate of the South Island, intercepting a very large part of the moisture from the seaward side. Between the mountains and the coast there are stations with as much as two hundred inches of rain annually, while Christchurch on the east coast has only about twenty-five inches, and there are a few stations with even a lighter precipitation. This dry region is mostly destitute of trees, the ground being covered with coarse tussock-grasses. The contrast between these dry grasslands and the densely forested regions of rainy Westland is most striking.

To the south of the great mountain range the conditions are more uniform, and the whole southern end of the South Island is covered with forest.

The North Island originally was almost completely covered with heavy forest, in which the most important tree was the Kauri pine (*Agathis australis*). Very little of this splendid forest remains, and the Kauri is almost extinct. A few small tracts have recently been reserved, and I had an opportunity of visiting one of these in the extreme northern part of the island. This new park is of limited extent, but is a typical example of the magnificent Kauri forest which once covered the desolated regions now occupying most of the surrounding country.

The Kauri is entirely different in appearance from any conif-

FIG. 7. KAURI FOREST, NORTH ISLAND, NEW ZEALAND

erous tree with which the American botanist is familiar. In its younger stages it shows the symmetrical pyramidal habit of most conifers, but the early branches finally fall off, leaving a perfectly smooth cylindrical bole with very little taper. This columnar trunk may reach a height of sixty to eighty feet, or even more, with a diameter of eight to ten feet, or it is said of twice this size. At the top there are several enormous diverging branches forming an immense spreading crown which overtops the other trees of the forest and gives the tree a most characteristic appearance.

The interior of the Kauri forest, with the huge smooth gray columnar trunks, is most impressive, and only rivalled by the great coniferous forests of the Pacific Coast, or the Cyptomerias of Japan. The New Zealand Kauri must rank as one of the giants of the vegetable kingdom.

Associated with the Kauri are a number of other trees, including several other Conifers or rather Taxads, as these belong to the Yew family. Of the latter the most important are the "Totara" (*Podocarpus Totara*) and "Rimu" (*Dacrydium cupressinum*), both valuable timber trees. The curious *Phyllocladus trichomi-noides* with flattened twigs (cladodes) looking like small fern-leaves, is not uncommon in this region. Some other characteristic trees are *Weinmannia sylvicola* (Saxifragaceae), said to be the commonest tree in New Zealand, and *Beilschmiedia tarairc*, belonging to the Lauraceae.

A number of fine shrubs, *e. g.*, Coprosma, Pittosporum, Nothopanax and others are common, and as in all New Zealand forests ferns are much in evidence. The abundant and beautiful tree-ferns lend a special charm to the New Zealand forest. The finest of these is *Cyathea medullaris*, which may reach a height of upwards of fifty feet and is the finest tree-fern with which I am acquainted.

Other interesting ferns are several species of Gleichenia, and the climbing fern, *Lygodium articulatum*, which is said to climb to the top of lofty trees. Filmy ferns (Hymenophyllaceae) are common in the damp shady woods, but are hardly as abundant or luxuriant as in the rain-forests of the South Island.

Epiphytes abound in the rain-forests and include many conspicuous mosses and liverworts as well as ferns and various flowering plants. Among the latter are a number of orchids, but these are mostly inconspicuous species, far inferior in beauty to some of the fine Australian epiphytic orchids. Perhaps the most conspicuous epiphyte is a very common liliaceous plant, *Astelia solanderi*, forming great tufts of stiff sword-shaped leaves on the trunk or branches of many trees. It very often is seen on the slender stem of the Nikau palm, forming great bunches completely surround-

FIG. 8. TREEFERNS, NEW ZEALAND

ing the trunk. This palm (*Rhopalostylis sapida*), is the only palm native to New Zealand.

Where the land has been cleared it is often invaded by the ubiquitous bracken (*Pteridium aquilinum*), and another plant which quickly takes possession is the "Manuka" (*Leptospermum scoparium*), closely resembling some of the Australian species. When in bloom the shrub is decidedly ornamental, with myriads of pretty white flowers.

In open, more or less swampy districts, all over New Zealand, two extremely characteristic plants can hardly fail to attract attention. These are the native "flax" (*Phormium tenax*) and the "cabbage-tree" (*Cordyline australis*), often grown in California under the name Yucca-palm. The flax yields an abundant and valuable fibre, which is manufactured on an extensive scale and is one of the most important products of the country. At the time of my visit both of these striking plants were in flower. The flax sends up from its tuft of broad leaves, five or six feet high, scapes about twice as tall, bearing racemes of tubular red flowers which are much frequented by honey-sucking birds. The stately Yucca-like Cordylines bear immense panicles of small white fragrant flowers.

Among the most widespread trees of New Zealand are several species of Metrosideros, a genus occurring throughout Polynesia and Australasia. *M. robusta*, the "Rata," is a very beautiful tree with glossy green leaves and bright red flowers. Like Eucalyptus, to which it is not very distantly related, the bright-colored stamens are the showy part of the flower. Another species, *M. tomentosa*, also with showy flowers, is abundant about Auckland, and several other species, some of them climbers, occur in various parts of New Zealand. *M. robusta* begins life as an epiphyte, the trunk of the older tree being made up of the united descending roots, as is so often the case in many species of Ficus.

The southern portion of the North Island has a somewhat different vegetation from that of the Auckland district. The Kauri is quite absent from this region, and in some districts there are forests of evergreen beeches much like those of the South Island.

In the immediate vicinity of Wellington the forest shows many of the same trees as that further north, *e. g.*, Podocarpus, Dacrydium, Metrosideros, Weinmannia, Beilschmiedia and others. Among these is one of the two species of Proteaceae found in New Zealand. This is a handsome tree, *Knightia excelsa*, somewhat resembling the Australian Banksias.

One of the most interesting small trees is a Fuchsia, *F. excorticata*, New Zealand having three species of this otherwise exclusively South American and Mexican genus.

Photograph by Dr. L. Cockayne.

FIG. 9. CABBAGE-TREES (CORDYLINE AUSTRALIS) AND NEW ZEALAND FLAX (PHORMIUM TENAX)

Shrubby Compositae are common in New Zealand. The genus Olearia, much like Aster, is well represented, some species having fine flowers, others like *O. ilicifolia* with handsome evergreen foliage. Another peculiar genus is *Raoulia*, which includes the "vegetable-sheep," *R. eximia*. Some other characteristic shrubs noted near Wellington are species of Melicytus, Elaeocarpus, Myrsine and Sophora. *S. tetraptera*, with brilliant yellow, very conspicuous flowers, is one of the few really showy New Zealand shrubs.

Wellington has an attractive if not large botanical garden of which the most interesting feature is a small ravine in which are growing many of the native trees and shrubs as well as some fine ferns and liverworts. Some of the treeferns are very tall and make a fine show. Of the liverworts the most notable is the remarkable *Monoclea Forsteri*, a giant among liverworts. This species is abundant about Wellington and also in various part of the South Island. The only other species known occurs in tropical America.

In the botanical gardens in Wellington are some fine exotic conifers, including a number of Californian species. One of these, the Monterey pine (*P. radiata*) is extensively planted in New Zea-

land, where it grows with extraordinary rapidity and furnishes a large amount of timber.

Across the harbor from Wellington at Day's Bay is a considerable extent of forest made up almost exclusively of two species of evergreen beeches (*Nothofagus fusca* and *N. Menziesii*). This forest is much more open than the mixed forest which prevails over most of the country near Wellington. These beeches, except for their much smaller leaves, are not unlike the true beeches of northern forests. They also remind one, in general habit, of the tree alders of the Pacific Coast.

Cook's Strait, separating the North and South Islands, does not seem to form an appreciable barrier to the migration of plants between the islands, there being little difference in the vegetation on the two sides of the Strait. Probably the separation of the two islands took place at a comparatively recent date, so that there has not been time for any marked change in the vegetation.

The important city of Christchurch is surrounded by the famous Canterbury Plain, an open grassland which like our western prairies is admirably adapted to agriculture.

The trip across the South Island from Christchurch to the west coast is full of interest to the botanist and includes some magnificent scenery. I had the good fortune to be accompanied by Dr. L. Cockayne, the well-known botanist, whose knowledge of the native flora is both extensive and accurate.[3]

The Canterbury Plain, where it has not been cultivated, is covered with tussocks of coarse grass, and this is true also of the lower slopes of the mountains on the eastern side. The most abundant species is *Festuca Novae Zealandeae*, but *Poa caespitosa* was another common and conspicuous species.

The change from this open grassland to the first beech forest is very abrupt, and marks the beginning of the western rainy district. The beech forest is very dense, and composed exclusively of the mountain beech (*Nothofagus Cliffortiana*).

At the summit of Arthur's Pass, about 3,000 feet elevation, the increasing moisture becomes more evident. The open stony ground supports a heavy growth of herbaceous plants and low shrubs. In this formation is found perhaps the most beautiful of all new Zealand flowers, *Ranunculus Lyallii*. This fine plant has very large undivided peltate leaves, and clusters of pure white flowers two inches or more in diameter, borne on stout stalks a foot or more in height. Another charming flower is *Ourisia macrocarpa*, with large flowers something like Mimulus.

[3] Dr. Cockayne's book, "New Zealand Plants and Their Story," Wellington, 1919, is an admirable account of New Zealand vegetation.

The sub-alpine scrub of this region is composed of a number of very characteristic species. The most casual observer cannot fail to note the Dracæna-like *Dracophyllum Traversii*, a small tree with clusters of reddish leaves at the tips of the straggling branches. In spite of its Yucca-like habit, this is a heath of the family Epacridaceae. Various shrubby Veronicas, a genus developed to a remarkable degree in New Zealand, are abundant and several shrubby Compositae (Olearia, Celmisia, Senecio) abound. A curious leafless leguminous shrub, *Carmichælia sp.*, is noted and a species of Gaultheria, and an Araliad (*Pseudopanax lineare*) are not uncommon. Along the roadside the mountain flax (*Phormium Colensoi*) is frequent. The descent on the west side, through the magnificent Otira Gorge, is one of the finest pieces of scenery in New Zealand. The very steep walls of the gorge are densely covered with luxuriant forest from crest to base.

The very heavy rainfall of this district is attested by the luxuriant rain-forest which reaches its maximum development on the west side of the range. At first there is some admixture of beech, but this finally disappears and in the typical Westland rain-forest is quite absent.

The banks along the roadside show a constantly increasing profusion of ferns, liverworts, and moisture-loving herbs, like violets, Hydrocotyle and the interesting Gunnera, a genus particularly developed in New Zealand.

Tree-ferns, which had not been seen at the higher elevations, increase in size and numbers as the lowlands are approached and in the lowland forest form a conspicuous and beautiful feature.

The Westland rain-forest is one of extraordinary luxuriance. The extremely heavy precipitation and mild temperature result in a rich profusion of vegetation that has all the aspects of a genuine Malayan rain-forest. Composed of exclusively evergreen trees and shrubs, draped with lianas and epiphytes and interspersed with thousands of noble tree-ferns, it was hard to believe that this forest was in latitude 43°, corresponding in the United States to the latitude of Buffalo.

This forest is of the type called "Taxad" by Cockayne, the most important trees belonging to the taxaceous genera Podocarpus and Dacrydium. In the swampy areas the "white-pine" *P. dacrydioides* predominates, a very tall tree with fine straight trunk yielding valuable timber. Of the angiospermous trees the most abundant is *Weinmannia sylvicola*, a tree of Malayan affinity, and its relative, *Quintinia acutifolia*, both belonging to the Saxifrage family. A very common large shrub is *Aristotelia racemosa*, with rather attractive pinkish flowers, and other common shrubs are species of Coprosma, *Metrosideras lucida*, and *Pseudopanax crassifolia*.

Ferns and other Pteridophytes abound in these wet forests. Various species of Lycopodium are abundant, and also the curious Tmesipteris. Of the tree-ferns, the commonest is *Dicksonia squarrosa*, sometimes twenty to thirty feet high. Less abundant is *Hemitelia Smithii*. Of the abundant epiphytic growths the most beautiful are the filmy ferns (Hymenophyllaceae) which in these Westland forests attain their finest development. Another extremely beautiful fern is *Todea* (*Leptopteris*) *superba*.

As might be expected, these supersaturated forests are a veritable garden of mosses and liverworts which drape the trees and form a thick carpet on the ground and big cushions over every prostrate log and stump. Great tussocks of Sphagnum are common about the pools, and now and then one encounters colonies of the giant *Dawsonia superba*, the last word in moss development.

The abundance and luxuriance of the liverworts is astounding; indeed, it is doubtful if anywhere else in the world is a richer growth of these interesting plants to be found.

Of the lianas the most interesting is *Freycinetia Banksii*, a distinctly tropical genus belonging to the screw-pine family, abundant throughout Polynesia and the Malayan region.

Everywhere in the New Zealand rain-forests there is a rich development of epiphytes and climbing plants. Of the epiphytes there are two categories, those that begin life as epiphytes, but later become rooted in the ground, and those which retain permanently the epiphytic habit. Among the latter are many ferns, Lycopods, Mosses and liverworts, as well as a good many flowering plants like Peperomia, various orchids, Astelia, etc. Of the ferns the filmy ferns or Hymenophyllaceae are especially numerous and beautiful.

Several species of New Zealand trees begin life as epiphytes. The seeds germinate in the branches of some tree and presently the young plant sends out roots which descend the trunk of the host-tree until they reach the earth. In course of time these descending roots coalesce in a more or less solid trunk and the host-tree may be completely strangled in the process. The "rata" (*Metrosideros robusta*) is the best known of these temporary epiphytes. Others are *Dracophyllum arboreum* and *Griselinea littoralis*.

Some of the climbing plants are great woody lianas, whose stout cables are thrown from tree to tree. One of the biggest of these is a huge bramble, *Rubus australis*, whose stems, sometimes six inches in diameter at the base, reach the tops of the tallest trees. Freycinitia climbs by means of roots, clinging to the trunks of trees, and some species of Metrosideros have a similar habit. Other common climbing plants are species of Clematis, Par-

sonsia and Mühlenbeckia and the climbing fern *Lygodium articulatum*.

Compared with Australia there is a remarkable scarcity of brilliantly colored flowers, a large proportion of the plants having white or greenish flowers. The bright red flowers of some species of Metrosideros, *Clianthus puniceus* and the native flax, bright yellow of *Sophora tetraptera,* the blue of many Veronicas and the blue or purple of some of the Compositae are the most marked exceptions to the rule.

Weeds

As in all countries where the white man has settled there have come with him many plant immigrants, some of which are not entirely welcome. These weeds hail from many lands. In the hotter and dryer parts of Australia they may come from such tropical countries as India, Brazil or Africa, while in the more temperate regions of southern Australia and New Zealand they are largely from northern Europe and America, *e. g.*, thistles, sorrel, dock, plantain and other familiar weeds.

Parts of Australia have been invaded by species of prickly pear (Opuntia) from America, which are a very serious pest. It has been said that in Queensland 30,000,000 acres of land have been invaded by one species which has caused immense damage.

From America have also come species of cockle-bur (Xanthium) and Stramonium, as well as several other pestilent weeds. In the moister cooler regions of Australia and New Zealand, the common European blackberry, sweet brier and gorse have escaped from cultivation and become very persistent and troublesome weeds.

A number of plants from the Cape, whose climate is very similar to that of Australia, have become completely naturalized. It is not uncommon to see the familiar calla growing in ditches and low ground, and several of the beautiful Iridaceae from South Africa—Ixia, Sparaxis, Watsonia and Homeria—very often are seen growing along the railway embankments. The latter is said to be poisonous and may perhaps be called a weed. This name may also be given to the "Cape-weed" (*Cryptostemma calendulacea*), a daisy-like Composite which is extremely abundant.

Conclusion

Attention has already been called to the evident close relationships existing between the Australian "scrub" floras and those of the Indo-Malayan regions. The rain-forests of Queensland and New South Wales may be looked upon, with little question, as the remnants of a much more extensive flora which occupied these regions when they were united with New Guinea and separated

from the ancient Western Australian continent. It is generally believed that in the latter, which was probably much larger than at present, the ancestors of the characteristic types which now dominate the flora of the greater part of modern Australia had their origin.

In the old Western continent, completely isolated from other lands, there was an extraordinary development of a comparatively small number of families. The most conspicuous examples of this are the Myrtaceae, with over 200 species in Eucalyptus alone; Leguminosae, especially Acacia with over 400 species, and many peculiar Papilionaceae; Proteaceae with over 600 species (Grevillea, Hakea, Banksia, etc.). A few families, *e. g.*, Candolleaceae, Goodeniaceae, are almost exclusively Australian and especially abundant in Western Australia.

These peculiar Australian plants are largely xerophytic, and after the union of Eastern and Western Australia it may be assumed that the extreme aridity and poor soils of much of the central part of the continent would be much more favorable to these Western xerophytes than to the Malayan types of the East which have evidently been largely evicted by the drought-resistant West Australian immigrants, and are now restricted to comparatively limited areas where there is good soil and abundant moisture.

The autochthonous types have for the most part remained in Australia. Eucalyptus, Acacia, a few Proteaceae and some others are represented in the savannahs of Southern New Guinea and the dryer portions of the Malay Archipelago; and a few genera range through Polynesia; but the great majority of the true Australian species are unknown outside the Australian continent.

In the southeast, and especially in Tasmania, there is a marked infusion of plants whose relationships are with the Andean and Fuegian vegetation of South America. Most of these occur also in New Zealand.

Comparing New Zealand with Australia, there is found a good deal in common in the floras of the northern districts, *i. e.*, the Malayan rain-forest vegetation. This type is, however, of very much greater importance in New Zealand, where in spite of a much cooler climate, a large proportion of the trees and shrubs are more or less closely related to Malayan ones.

There is strong evidence of former connections with the tropical regions to the North, and it is quite as likely that the Malayan genera which New Zealand shares with Australia have been derived from the North and not directly from Australia.

The distinctively Australian genera are relatively few in New Zealand, and a striking feature of the flora is the absence of such

predominant Australian genera as Eucalyptus and Acacia. The family Myrtaceae, with over 800 species in Australia, has barely twenty in New Zealand, only one genus, Leptospermum, being typically Australasian. The Proteaceae, which reach their maximum in Australia, with more than 650 species, have only two representatives in New Zealand. There are, however, a considerable number of Epacridaceae, and several Australian genera of orchids, as well as Compositae and Leguminosae. It has been suggested, however, that some of these forms might be of New Zealand origin and migrants into Australia.

Most of the ferns common to the two countries are widespread Australian-Malayan species, but mention should be made of one, *viz.*, *Todea barbara*, common to northern New Zealand and New South Wales and also found in South Africa.

The Fuegian genera already referred to are mostly shared by Australia and New Zealand. Of these there are twenty-two genera common to the two countries, among which may be mentioned Astelia, Muehlenbeckia, Drimys, Nertera and the evergreen beeches, Nothofagus.[4]

There are sufficient resemblances between the floras of Australia and South Africa to indicate some former land connections between the two, but it is probable that the connection was severed at a very remote period.

In South Africa, as in Australia, there is a remarkable development of Proteaceae, but there are no genera common to the two, indicating a very long period of separation. The true heaths (Ericaceae) which are a marked feature of the South African flora are replaced in Australia by the Epacridaceae. It has been suggested[5] that the two families are offshoots of a common stock, differentiated since the disappearance of a former land connection.

It is pretty well agreed that at one time all the great southern land masses were connected more or less completely. The name "Gondwana Land" has been given to an assumed great southern continent, existing in late Permian time, and embracing a large part of the present South American, African and Australian continents, as well as parts of India and Malaya. Just how long these connections remained is not entirely clear, but if they persisted into the Cretaceous, or early Tertiary, this would explain many of the apparently anomalous facts of the present distribution of the floras of the southern hemisphere.

We have also to take into account the great antarctic continent. At present this is practically destitute of any terrestrial

[4] Cockayne, *loc. cit.*, p. 206.

[5] Maiden, *loc. cit.*, p. 181.

vegetation, but there have been found fossils indicating the former presence of a vegetation related to that of South America and New Zealand. Further investigation may show that there was a northward extension of the present antarctic continent, with climatic conditions much more favorable for vegetation, than exists at present.

If further discoveries of fossils should show that, as in the northern hemisphere during the Tertiary, there was also in the south a practically uniform flora encircling the globe, this would make comprehensible both the resemblances and differences now existing in the floras of the southern land-masses.

Migrants from this common southern flora later completely shut off in the present widely separated countries, would in course of time show greater or less divergence from each other, depending upon the amount of change in their environment. It might be expected that in the cool humid climate of New Zealand, the evolution of the primordial southern types would be very different from those subjected to the hot and arid conditions of Western Australia, which is supposed to be the birthplace of most of the strictly Australian plant-types.

EASY GROUP THEORY

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THE report that the title of the chair of "differential and integral calculus" in the University of Paris has recently been changed to "the theory of groups and the calculus of variations" may tend to create a desire on the part of a larger group of scientific men to understand the essence of a mathematical group and the rôle which the group concept is assuming in modern mathematical developments. The fundamental importance of the concepts of differential and integral calculus in various fields of science has long been recognized, and the change of title noted above does not imply that the theory of groups and the calculus of variations tend to supplant the differential and integral calculus. It does, however, imply that the former subjects are also sufficiently fundamental and fruitful to merit prominent recognition in a leading mathematical center.

Paris may justly claim a very large share in the early development of group theory. A Parisian, A. L. Cauchy, is commonly regarded as the founder of this subject, while other Parisians, including A. T. Vandermonde and E. Galois, did important pioneering work in this field. Although J. L. Lagrange is commonly regarded as a French mathematician his pioneering work in group theory was done before he settled in Paris. The first separate treatise on this subject was written by a Parisian. This work appeared in 1870 under the title *Traité des substitutions et des équations algébriques* by C. Jordan.

In group theory as well as in differential and integral calculus the first extensive formal or abstract developments are due to English and German mathematicians. In the case of the latter subjects the authors of these developments, *viz.*, Newton and Leibniz, are commonly regarded as its founders. Fortunately this has not yet been done as regards the former subject. Notwithstanding the fundamental importance of formal developments and abstract formulations the real life of mathematics abides in its contact with the concrete. In the case of group theory this contact has been emphasized especially by S. Lie, F. Klein and H. Poincaré. The rapidly increasing prominence of this theory during the last half

century is largely due to the writings of these three men, who have been leaders also in various other lines of mathematical activity.

A dominating mathematical concept, like a dominating personality, has a charm of its own, and creates a kind of atmosphere which is as invigorating as that of a real university or that which emanates from any group of real scholars. A fundamental notion of a mathematical group is that "there is no new thing under the sun." It is true that we speak here of generators and generational relations, but the objects which are generated were members of the group since the beginning of time and will remain members thereof throughout eternity. We study the group to perceive this sameness in its various forms and to understand the relative properties of the various elements which unite to make a single element of the group.

The non-technical meaning of the term group suggests little as regards its technical meaning except the invariance of the number of its elements. In a non-technical group one usually thinks of the elements as units which may or may not have the power of reproduction. In the former case the elements thus produced are usually new elements of the group. In the technical group the elements have necessarily the power of uniting, but when they unite they neither produce any new element nor lose their own identity. The union merely exhibits the possible decomposition of an element of the group, or the different ways of securing *e pluribus unum*. Union, unity and stability constitute the triumvirate of the theory of groups. The stability here noted is not the stability of statics but the stability of dynamics. It is a kind of invariance under transformations.

What is perhaps of most interest in this connection as regards the non-mathematician is the question why the concept to which we referred above is so fundamental in mathematics. It is well known that mathematical developments have been largely guided by the desire to secure intellectual penetration into the workings of nature. Do we find in nature numerous instances of the union of elements of the same kind to produce an element of this kind which is really not new but belongs to a totality which has been clearly defined? For instance, one may think of the totality of the transformations of space subject to the condition that the distance between every pair of points in space remains invariant. It is evident that if one such transformation is followed by another the two together are equivalent to a single transformation of the totality in question. Hence we say that this totality constitutes a group.

It is also clear that the totality of the natural numbers when they are combined by addition has the property that no new number arises from the combination of any two of them, or from the combination of one with itself. In both this totality and in the totality of transformation noted in the preceding paragraph it is evident that if x, y, z represent three elements of the totality and if any two of them are supposed to be known then the third is completely determined by the following equation:

$$x\,y = z$$

The term group is commonly used in mathematics in the restricted sense that the third of any three elements is completely determined by such an equation where any two of them are supposed to be given. Moreover, it is usually assumed that when any three elements are combined the associate law is satisfied, but it is not assumed that the commutative law is necessarily satisfied when two of them are combined.

Even when these restrictions are imposed there are instances of groups almost wherever one turns. It is true that in the vegetable and the animal kingdoms one sees new elements arising in profusion, and mathematics is naturally called on to deal also with such conditions, but if one looks deep enough here there seems to be a union of elements without loss of identity of the elements, and there seems to be nothing new in the profound formal physical sense. Hence one may see some significance in the following statement made by Poincaré shortly before his death: "The theory of groups is, so to say, entire mathematics, divested of its matter and reduced to a pure form."

In the groups noted above the number of elements is infinite. As instances of a finite group we may consider the six movements which transform a fixed equilateral triangle into itself and the eight movements which transform a fixed square into itself. Such special instances are, of course, of little interest to the general scientist except as illustrations. The thing that may be supposed to command the interest even of the educated layman is the fact that these very evident considerations appertain to a profound mathematical theory.

Group theory did not arise from such obvious considerations. After it was partially developed as an autonomous science some of its more obvious applications received special attention. A certain degree of difficulty seems to create the most favorable atmosphere for scientific developments. In group theory this atmosphere was created by the n roots of the algebraic equation of the following form:

$$x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_n = 0$$

It is customary to speak of x as the unknown and to call this an equation of degree n in one unknown. As a matter of fact the equation has n roots and all of these are unknown, so that it is really an equation in n unknowns. The constant coefficients $a_1, a_2 \ldots a_n$ were known to be symmetric functions of these n unknowns before the subject of group theory was developed.

The mysterious appearance of n unknowns to take the place of the one which presents itself openly is perhaps sufficient to create an atmosphere suitable for scientific endeavors. At any rate, it was in this atmosphere that our subject arose and hence we shall note here a few of the early steps in its development. It is true that these steps were taken by men who seemed to have no idea that they were dealing with notions which had the widest applications in other fields of mathematical endeavor. In fact, the early explorers of group theory died long before any one realized that the notions with which they were dealing were destined to permeate a large part of the science of mathematics.

The n roots of an equation of degree n with constant coefficients constitute a group in the non-technical sense of the term, but the group of this equation is something very different and lies much deeper. It relates to a certain totality of permutations of these n roots, or substitutions on these n roots, leaving invariant every possible rational function of these roots which is equal to a constant, and having the property that if a rational function of these roots is invariant under these substitutions it is equal to a constant. These fundamental properties of the n roots of the equation in question were first noted by E. Galois, a French mathematician of great renown, although he died before reaching the age of twenty-one years. They were sufficiently difficult to create an atmosphere suitable for the development of our subject as an autonomous science.

A study of the permutations of n things might at first appear to promise little of importance. It is true that before the time of Galois attention had been called to this subject by Lagrange and Vandermonde in connection with the question under what condition a rational function on n variables can be expressed rationally in terms of another such function, but it was not until long after the days of Galois that mathematicians began to realize the fundamental importance of this subject in the study of a large variety of mathematical questions. When the substitutions arising from these various permutations were studied by themselves they were seen to combine according to laws which are found almost everywhere when the data are sufficiently connected to admit mathematical treatment.

The reader who has given little attention to mathematical developments may be inclined to ask, If the notion group is so fundamental why did the ancients and even such eminent later thinkers as Descartes and Newton pay no explicit attention to it? Why does the theory of groups not have an ancient prototype like differential and integral calculus, whose prototype is found in the method of exhaustion of the ancient Greeks? Does it appear reasonable that a subject founded only three quarters of a century ago should really deserve such a dominating position in modern mathematics as is claimed for group theory in what precedes the present paragraph? Does the history of mathematics present any other instance of the sudden rise of a dominating concept extending into practically all the large branches of mathematics?

The fact that the last of these questions must be answered in the negative tends to enhance the interest in the others. This negative answer calls also for a word of caution for there is danger that the reader might infer from it that the subject of group theory has greater merit than really belongs to it. It seems that mathematical developments have always been guided by the group concept. In the words of Poincaré "the ancient mathematicians employed groups in many cases without knowing it." The main question in mathematical developments is that one gets on the right road. The ability to explain why one has chosen this road is of secondary importance. In fact, the best teacher is frequently unable to give a good account of his methods while a much inferior teacher may be able to talk glibly about methods.

Group theory is largely a method and those who are studying this subject by itself may be compared with those who are devoting their attention to methods of teaching. Just as the latter are not necessarily the best teachers so the former are not necessarily the best mathematical investigators. Possibly the bacteria which have tended to make the teachers colleges such a prominent feature of our modern universities have also caused the emphasis on group theory in modern mathematics. Just as some of our best teachers have never read a work on methods of teaching so some of the best mathematical investigators have never secured a speaking acquaintance with the notion of group. In both cases the real essence of the subject has been acquired unconsciously, or, at least, without the development of a formal language relating thereto.

The fact that modern mathematicians emphasize the group concept while the ancient and medieval mathematicians did not do this does not imply a change of mental attitude. Naturally the modern mathematicians secured a somewhat deeper insight into various subjects and thus discovered evidences of groups

which were unknown to the older mathematicians. Inspired by these groups they developed also the theory relating to the groups which the ancients used implicitly, but it is questionable whether the modern mathematicians would have developed a theory relating to the latter if they had not been inspired by the former. At any rate, they did not take any steps towards such a theory before they had this additional motive. These observations may serve as partial answers to questions raised above relating to the late development of our subject as an autonomous science.

The heading of the present article suggests that some of the developments of our subject can not be properly called easy. In fact, by far the larger part of these developments presuppose a rather extensive technical knowledge and hence they are unsuited for a popular article. Among all the scientists the mathematician works usually at the greatest distance from his postulates, and hence he has the greatest difficulty to exhibit the results of his toil to the public in the hope of securing appreciation, which he craves with the others of his fellowmen. In group theory this distance has become especially long even for a mathematical subject, but this theory does extend also into the experiences of all thoughtful persons. The present article aims merely to direct attention to the richness of the mathematical developments which have contact with these particular experiences and thus to secure an easier approach to some of this richness.

If a group contains a finite number of elements this number is called the *order* of the group. For instance, the 24 different movements of space which transform a cube as a whole into itself but interchange some of its parts constitute a group of order 24. The most elementary group of a given order g is cyclic; that is, it is composed of the powers of a single one of its elements. For instance, the g numbers which satisfy the condition that the gth power of each of them is equal to unity constitute this group of order g, where g is any natural number. It is evident that the 24 different movements which transform a cube into itself are not powers of a single one of them. Hence they constitute a noncyclic group of order 24. In fact, none of the elements of this group has to be raised to a higher than the fourth power in order to obtain unity, or the identity.

One of the fundamental problems of abstract group theory is the determination of all the possible groups of a given order g. It was noted above that there is one and only one cyclic group of every possible order g. When g is a prime number there is no other group of this order. This is also sometimes the case when g is composite but there is no upper limit to the number of groups

which may have the same composite order. That is, it is always possible to find a number g such that the number of the different abstract groups of order g exceeds any given finite number. In addition to the two groups of order 24 noted above there are 13 others, which were first completely determined in 1896 by the present writer. The lowest order for which the number of groups exceeds the order is 32. There are 51 distinct groups of this order.

The verification of several of these statements would carry us beyond easy group theory. They may serve, however, to exhibit a type of inquiry relating to our subject. Fortunately, some of the most important and far-reaching phases of this subject are also the easiest. For instance, the group of all the transformations of space which leave invariant the distances between every pair of points can easily be comprehended. Those geometric figures which can be transformed into each other under this group may be called equivalent and we may confine our attention to the study of geometric properties which remain invariant under the transformation of this group. We thus obtain a body of knowledge commonly called ***Euclidean Geometry,*** but this term is also often used with different meanings. Following the custom introduced by Gauss some still use it to denote all the geometry in which the parallel postulate is assumed.

It is clear that in geometry it is undesirable to endeavor to study every figure as an individual since one could not make much progress in this way. What people have always done in this subject is to confine their attention to invariants under certain infinite groups of transformations. It is true that the ancients did not specify these groups and that we do not usually do this now in a first course in elementary geometry, but for the advanced student, at least, the developments become much clearer if this specification is explicitly made. If we add to the transformations noted above those which do not preserve the size of the figures but do preserve their angles, so that all similar figures are regarded as equivalent, we obtain a larger group, which has been called the principal group of geometry. The body of knowledge relating to the invariants of this group is commonly known as *Elementary Geometry.* In particular, all circles are equivalent in this geometry and all squares are also equivalent here. Some writers call this geometry Euclidean Geometry. This is done, for instance, on page 61, volume 2, Pascal's *Repertorium der höheren Mathematik,* 1910.

These observations relating to the groups of geometry may serve also to support the implication noted above that group theory is often a kind of mathematical luxury. One can frequently get along without a knowledge of this subject where a knowledge

thereof would add greatly to the intellectual comfort. The fact that the mathematical world traveled far without making explicit use of this subject which now receives so much emphasis in work closely related to that which they were doing is perhaps best explained by viewing the matter from this standpoint. It need scarcely be added that group theory has also served to point out the way to easier methods of attack and to more powerful means of penetration, but this applies more especially to the more difficult group theory and hence lies outside the domain to which the heading of the present article relates.

In the opening sentence of this article we alluded to the fact that in the University of Paris there is now a chair entitled "the theory of groups and the calculus of variation." This should not be construed to mean that the developments of these two subjects have as yet much in common. In fact, there are few large mathematical subjects whose developments exhibit as little explicit use of group theory as those of the calculus of variations. Possibly the title noted above indicates that there will soon be a change in this direction. This title also raises the question whether our larger American universities should not have more chairs devoted to special subjects. The creation and occasional renaming of such chairs would tend to direct attention to leading investigators in various fields, an attention which often needs cultivation on the part of administrative officers.

THE HISTORY OF THE CALORIE IN NUTRITION

By MILDRED R. ZIEGLER

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THE nomenclature of a science is of vital importance; it is intimately bound up in the subject itself. Special technical words are used to describe the phenomena which are being studied. Lavoisier emphasized the importance of nomenclature in his "Traité Élémentaire de Chimie" (1789) when he stated: "Every branch of physical science must consist of three things; the series of facts which are the objects of the science; the ideas which represented these facts, and the words by which these ideas are expressed. Like three impressions of the same seal, the word ought to produce the idea, and the idea to be a picture of the fact . . .; we can only communicate false or imperfect impressions of these ideas to others, as long as precise terms are lacking."

The calorie as defined in the science of nutrition is a measure of food value. The significance of the word calorie as thus used to-day is not the same as its import when first introduced into the French language. To the student of nutrition the word connotes something quite different from the term as employed by the physicist. It is the amount of a food substance which on combustion in the body will yield energy—heat or work—equivalent to a calorie as understood by the physicists. Even the term as employed by the latter to-day has undergone a change from its original meaning (1845). As first defined the calorie represented the amount of heat required to raise one *kilogram* of water through one degree centigrade. It is well known that the same term now means the amount of heat required to raise one *gram* of water through one degree centigrade. The calorie, then, has had—and still does have—two somewhat unlike meanings according as the gram or kilogram of water is the unit of mass, the temperature of which is being changed and the energy required for this change is being considered. Both of these meanings are preserved in the scientific literature of to-day, the larger unit being designated as a large calorie and written Calorie.

It is quite evident that either the small calorie or the large Calorie may be the more convenient unit with which to express heat change depending upon the magnitude of the change being studied. The physicist in expressing the amount of energy supplied in the form of heat required to raise one gram of water from its freezing point to its boiling point obviously is dealing with a relatively small energy change which if expressed in heat units, as discussed above, is in the neighborhood of one hundred calories. In such cases the little calorie is the convenient unit to employ; on the other hand experiments in the field of nutrition have demonstrated that the energy changes are of such magnitude that the Calorie is the more convenient unit for expressing them quantitatively.

The derivation of the word is very interesting; it has developed from the old French word "calorique" which was derived from the Latin term "calor." Lavoisier introduced "calorique," which was defined at that time as an elastic fluid containing the hidden cause of the sensation of heat and to which the phenomena of heat were attributed. This meaning was abandoned with the theory to which it belonged. As far as a review of the literature reveals Bouchardat (1845) was probably the first to define it according to the modern physical conception. In his "Physique élémentaire" we read: "Unité de chaleur—On designe sous le nom d'unité de chaleur ou de calorie celle qui est nécessaire pour élever 1 kilogram d'eau d'un degré du thermomèter centigrade."

The idea of measuring heat in this way had been in general use for some time, but the word calorie had not been introduced earlier.

Pouillet (1832) in his "Physique" defined the heat liberated by combustion of different substances as "Élévation de témperature que 1 gr. de chaque substance en se brûlant avec l'oxigène communiquerait a 1 gr. d'eau." He ascribed the value 6195° to alcohol which checks closely with its caloric value as now known. Although the French had coined the word in the year 1845, it apparently was not in general use for some time; for in 1852 Favre and Silbermann[1] in an article on heat wrote: "We shall repeat that the unit which we have adopted is that adopted by all physicists, that is, the quantity of heat necessary to raise 1 gram of water 1 degree and which they call unit of heat or calorie." The Germans evidently took the word from the French, but it is difficult to determine at what time. Gmelin (1817-19) in his

[1] Favre and Silbermann: *Ann. de chim. et phys.*, 1852, Ser. 3, xxxiv, 357.

"Handbuch der Chemie" uses the same idea as the calorie unit but refers to it as did Pouillet. As late as 1871 Senator[2] deemed it necessary in an article on heat production and metabolism to define the word "calorie" in a footnote.

According to a contributor to Murray's "New English Dictionary on Historical Principle" (1888), the word calorie was first introduced into English in 1870 by T. L. Phipson in his translation of "The Sun" by the French astronomer, Amédée Guillemin. Before this time the English had spoken of heat units which referred to Joule's mechanical equivalent of heat, *viz.*, 1 kilog. of water raised 1°C=423 metrekilogs. This was the term used in Frankland's[3] classic treatise "On the Origin of Muscular Power."

The derivation of the word calorie has not revealed its meaning; for that it is necessary to consider the history of animal heat, combustion and the potential energy of the foodstuffs. To the old scientists animal heat offered a difficult problem, surrounded with much mystery. They could not explain it by any known chemical or physical laws. They did not assign any cause to it, but described it as an innate quality, something "vital" situated in the heart and distributed to the body by the blood vessels (Plato, Aristotle, Galen). The principal function of the blood was to distribute the heat, while the great function of respiration was to cool this distributing medium. Mechanical and chemical notions were accorded to heat production. As a history of the calorie is concerned only with the chemical theories, the mechanical ones described by Haller (1757)[4], Boerhaave (1709)[5] and contemporaries will not be discussed here. Willis (1670)[6] was probably the first to consider an idea of combustion in heat production. He said that there was a "combustion" in the blood dependent upon fermentation excited by the combination of different chemical substances. All the chemists of the time considered animal heat a product of a "fermentation" occurring in the blood while in the heart. Willis' term "combustion" was not in accord with the modern conception in which oxygen is essential, as this element had not been discovered. A more correct opinion was enunciated by Mayow (1674)[7] who had experimented on the elements of the

[2] Senator: *Centralbl. f. d. med. Wiss.*, 1871, IX, 737, 753.

[3] Frankland: *London, Edinburgh, and Dublin Phil. Mag. and Jour. of Sc.*, 1866, xxxii, 182.

[4] Haller: "Elementa Physiologiæ," 1757.

[5] Boerhaave: "Aphor. cum Notis Swieten," pp. 382-675.

[6] Willis: "De Accensione Sanguinis," 1670.

[7] Mayow: "Tractatus Quinque," Oxonii, 1674.

air and described a "nitro-aerial spirit" (oxygen). He held that the function of respiration was not to cool the blood but to enable this fluid to absorb nitro-aerial gas for generating heat. Mayow's theory did not appear to make any considerable impression upon his contemporaries. It was not until Joseph Black's (1755)[8] experiments on fixed air were performed that more correct ideas prevailed. He showed that the gas expired from the lungs is the same as that produced by combustion of fuel, thus establishing a relationship between combustion and respiration. Black was forced to relinquish his theory by his contemporaries who claimed that if the lungs were the sole seat of combustion the amount of heat produced therein would be so great that the vitality of the organ would be destroyed.

The production of heat by a combustion of foodstuffs was merely suggested at this time (1677) with no air of conviction that such could be the case. It appears that Descartes should receive the credit for first suggesting the correct theory regarding heat production in the animal body in his "De Homine" (1662). He thought that the change produced in the food in the stomach was analogous to the heat produced when water is poured upon lime or aqua fortis on metals. Hunter (1761) in his dissertation "On Blood" incidentally remarks that "the source of heat is in the stomach." He had previously expressed dissatisfaction with all prevailing theories of animal heat. Hunter's idea is to be regarded merely as his suggestion, with as yet no clear-cut data to justify its assumption of the rank of an established theory.

It remained for Lavoisier, the father of modern chemistry, to prove by his carefully performed experiments that animal heat is not caused by any mystical "vital force" as the ancients believed, but is a phenomenon analogous to the burning of a candle, namely, the combustion of carbon. He repeated, verified and added experiments to those of Black and Priestley, and explained more explicitly than had ever been done before the source of animal heat. In 1780 in his "Mémoire sur la Chaleur" published in collaboration with Laplace he gave in detail the theory of heat essentially as we have it to-day. By means of the calorimeter the heat evolved during the formation of a definite quantity of carbonic acid was compared with that produced during the formation of the same amount of this compound during respiration. These investigators saw that in such transformations identical amounts of heat were produced. They concluded that animal heat is derived from the oxidation of the body's substance.

[8] Robison: "Joseph Black," Edinburgh, 1803.

The publications of Lavoisier's time and before that had spoken of heat as "chaleur." Pouillet (1832), the physicist, remarked: "Scientists confused the cause of heat with its effect. They called it chaleur, fluide igné, matière du feu. Finally in reforming the chemical nomenclature Lavoisier, Bertholet, Morveau and Fourcroy have called it calorique. This term was adopted by the physicists of the time; and they reserved the word 'chaleur' to designate the science which treats of the properties, effects and laws 'du calorique.' "[9] An interesting use of "calorique" is found in the "Mémoire sur la Respiration des Animaux" published in 1789 by Lavoisier and Seguin. They state, "1. Que le calorique (matière de chaleur) est un principe constitutif des fluides (Sous ce nom générique nous comprenons les airs et les gaz.) et que c'est à ce principe qu'ils doivent leur état de'expansibilité, leur élasticité, et plusieurs autres des propriétés que nous leur connaissons."[10] There is no reference to a heat unit, calorie, in Lavoisier's publications. He defines the amount of heat in terms of the weight of ice melted in a given experiment.

Although the early physiologists suggested the correct source of animal heat, it is significant that they considered heat a simple chemical reaction, as stated by Descartes. Apparently they had no idea of a combustion as understood in the modern sense occurring in the tissues, for they did not consider the source of animal heat in starvation. Even physiologists of 1803 like Richerand do not consider starvation in their texts.

Lavoisier taught us the true cause of animal heat, but he could not explain the theory as to-day because the law of the conservation of energy had not been formulated. Joule (1844) by his masterly researches evaluated the mechanical equivalent of heat, and largely on this basis Mayer (1845) gave expression to the law of conservation of energy, the application of which was made by Helmholtz. Energy cannot be destroyed or created. As even the ancient Greek Democritus (370 B. C.) once said, "Nothing can ever become something nor can something become nothing"—*ex nihilo nihil fit, et in nihilum nihil potest reverti.*

Dulong, Depretz, Regnault, Reiset, Pettenkofer and Voit contributed considerable to the study of animal heat and in turn helped to perfect the calorimeter. It remained for Rubner[11] to

[9] "Chaleur" probably would be translated thermodynamics and "du calorique" heat.

[10] Lavoisier et Seguin: "Mémoire sur la Respiration des Animaux," 1789.

[11] Rubner: *Zeit. f. Biologie,* 1883, xix, 313; 1885, xxi, 250; 1886, xxii, 40; 1894, xxx, 73.

prove that physiological activity in the animal body is no exception to the operation of the law of conservation of energy. He showed that chemical change is the cause of animal heat. He discovered that the animal is a living calorimeter in which food, when burned, changes into another form of energy. Rubner, experimenting with dogs, measured the body's income and output of energy, and determined the relation of heat produced by oxidation of the foodstuffs ingested to the products which are given out. This figure he compared with the energy produced as measured by the calorimeter and found an agreement within one per cent. This remarkable result has since been confirmed by other investigators who have been aided by modern methods, the refinements of which are difficult to describe adequately. Rubner's important conclusions are that energy is not destroyed or created by the living organism; that the foodstuffs are oxidized within the body in a manner similar to their oxidations in a chemical laboratory. The law of conservation of energy therefore applies to the animate as well as to the inanimate world.

When calories are mentioned in nutrition, it is from the point of view of food fuel value. The calorie value of a diet is a factor of great importance in nutrition. Frankland (1866) was the first to determine this for various foodstuffs by oxidizing them in a calorimeter. He did not express the results in "calories" but rather as "heat units" (*loc. cit.*) which had the same value. Stohmann (1879)[12] and Rubner (1883) were apparently the first to use the term calorie as it is now applied in the science of nutrition. Rubner made three outstanding contributions regarding the calorie in nutrition: (1) He applied its present day meaning to the term; (2) he determined the caloric value of protein, fat and carbohydrate, figures which are widely used in determining the energy content of a diet; (3) he drew the distinction between the absolute and physiological heat values of foods. By absolute heat value he meant the amount of heat yielded by a substance when oxidized in a bomb calorimeter; the amount of heat produced by the substance in question when burned within the animal body he regarded as its physiological heat value. These values may or may not be identical, a fact which is of fundamental importance in the science of nutrition.

Calorie as a mere word explains nothing. It is a symbol for an idea, however, which, as we have seen, has undergone changes brought about by the development of several sciences. Ancient

[12] Stohmann: *Journ. f. prakt. Chem.*, 1879, xix, 115.

and hazy notions regarding the phenomenon of fire and combustion first contributed to this concept, placed on a firmer foundation by the clarifying influence of Lavoisier. The broad generalization regarding force in nature, receiving its impression in the law of the conservation of energy, played its rôle in the evolution of the idea and should probably be regarded as the most important factor contributing to the development of this notion as it exists to-day. The history of the calorie in nutrition, therefore, is wrapped up in the history of nutrition itself and the fundamental natural sciences upon which this branch of knowledge rests.

SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture IV—Ants, Their Development, Castes, Nesting and Feeding Habits

II

There is throughout the animal kingdom, as I believe Espinas was the first to remark, a clear correlation on the one hand between a solitary life and carnivorous habits and on the other hand between social habits and a vegetable diet. The beasts and birds of prey, the serpents, sharks, spiders and the legions of predacious insects all lead solitary lives, whereas the herbivores, rodents, granivorous and frugivorous birds and plant-eating snails and insects are more or less gregarious. Man himself is quite unable to develop populous societies without becoming increasingly vegetarian. Compare, for example, the sparse communities of the carnivorous Esquimaux with the teeming populations of the purely vegetarian Hindoos. The reasons for these correlations are obvious, for plants furnish the only abundant and easily obtainable foods and, at least in the form of seeds and wood, the only foods that are sufficiently stable to permit of long storage. In the previous lectures I have shown that the social beetles and bees are strictly vegetarian and that the social wasps, though descended from highly predatory ancestors, are nevertheless becoming increasingly vegetarian like the bees. The ants exhibit in the most striking manner the struggle between a very conservative tendency to retain the precarious insectivorous habits of their vespine ancestors and a progressive tendency to resort more and more to a purely vegetable regimen as the only means of developing and maintaining populous and efficient colonies. Anthropologists have distinguished in the historical development of human societies six successive stages, designated as the hunting, pastoral, agricultural, commercial, industrial and intellectual. Evidently the first three, the hunting, pastoral and agricultural, are determined by the nature of the food and represent an advance from a primitive, mainly flesh-consuming to a largely vegetarian regimen. Lubbock showed that the same three stages occur in the same sequence in the phylogenetic history of the ants. At the present time we are able to give even greater precision to his outlines of this evolution.

[1] Lowell Lectures.

All the primitive ants are decidedly carnivorous, that is predatory hunters of other insects. That this must have been the character of the whole family during a very long period of its history is indicated by the retention of the insectivorous habit, in a more or less mitigated form, even in many of the higher ants. Always striving to rear as many young as possible, always hungry and exploring, the ants early adapted themselves to every part of their environment. They came, in fact, to acquire two environments, each peopled by a sufficient number of insects, arachnids, myriopods, etc., to furnish a precarious food-supply. Most of the ants learned to forage on the exposed surface of the soil and vegetation and became what we call epigæic, or surface forms, while a smaller number took to hunting their prey beneath the surface of the soil and thus became hypogæic, or subterranean. Many of the latter are very primitive but their number has been repeatedly recruited from higher genera, which by carrying on all their activities within the soil have found a refuge and surcease from a too strenuous competition with the epigæic species. We have here some very interesting cases of convergence, or parallel development, since the underground habit has caused the workers, which rarely or never leave their burrows, to lose their deep pigmentation and become yellow or light brown and to become nearly or quite blind. As will be evident in the course of my discussion, the tendency towards vegetarianism is apparent among both the epigæic and hypogæic forms.

The ants belonging to the oldest and most primitive subfamilies, the Ponerinæ, Dorylinæ and Cerepachyinæ and also to many of the lower genera of Myrmicinæ, feed exclusively on insects and therefore represent the hunting stage of human society. Owing to the difficulty of securing large quantities of the kind of food to which they are addicted, many of the species form small, depauperate colonies, consisting of a limited number of monomorphic workers. Many of these species lead a timid, subterranean life. In the size of their colonies, which may comprise hundreds of thousands of individuals, the Dorylinæ alone constitute a striking exception, but one which proves the rule. These insects, known as driver, army or legionary ants and very largely confined to Equatorial Africa and tropical America, are strictly carnivorous, but being nomadic and therefore foraging over an extensive territory, are able to obtain the amount of insect food necessary to the growth and maintenance of a huge and polymorphic population. They are the famous ants whose intrepid armies often overrun houses in the tropics, clear out all the vermine and compel the human inhabitants to leave the premises for a time. In Africa they have been known to kill even large domestic animals when they were tethered or penned up and thus prevented from escaping.

The pastoral stage is represented by a great number of Myrmicine and especially of Formicine and Dolichoderine ants which live very largely on "honey-dew." This sweet liquid, concerning the origin of which there was much speculation among the ancients, is now known to be the sap of plants and to become accessible to the ants in two ways. First, it may be excreted by the plants from small glands or nectaries ("extrafloral nectaries") situated on their leaves or stems, where it is eagerly sought and imbibed by the ants. Second, a much more abundant supply is made accessible by a great group of insects, the Phytophthora, comprising the plant-lice, scale-insects, mealy-bugs, leaf-hoppers, psyllids, etc., which live gregariously on the surfaces of plants. These Phytophthora pierce the integument of the plants with their slender, pointed mouth-parts and imbibe their juices which consist of water containing in solution cane sugar, invert sugar, dextrin and a small amount of albuminous substance. In the alimentary canal of the insects much of the cane sugar is split up to form invert sugar and a relatively small amount of all the substances is assimilated, so that the excrement is not only abundant but contains more invert and less cane sugar. This excrement or honey-dew either falls upon the leaves and is licked up by the ants or is imbibed by them directly while it is leaving the bodies of the Phytophthora. Many species of ants have learned how to induce the Phytophthora to void the honey-dew by stroking them with the antennæ, protect and care for them and even to keep them in specially constructed shelters or barns. Some ants have acquired such vested interests in certain plant-lice that they actually collect their eggs in the fall, keep them in the nests over winter and in the spring distribute the hatching young over the surface of the plants. Linnæus was therefore justified in calling the plant-lice the dairy-cattle of the ants ("*hæ formicarum vaccæ*"). This dairy business is, in fact, carried on in all parts of the world on such a scale and with so many species of Phytophthora that it constitutes one of the most harmful of the multifarious activities of ants. Their irrepressible habit of protecting and distributing plant-lice, scale-insects, etc., is a source of considerable damage to many of our cultivated plants and especially to our fruit-trees, field and garden crops. Ants mostly attend Phytophthora on the leaves and shoots of plants, but quite a number of species are hypogæic and devote themselves to pasturing their cattle on the roots. Thus our common garden ant (*Lasius americanus*) distributes plant-lice over the roots of Indian corn.

The habit of keeping Phytophthora was probably developed independently in many different genera, and it is easy to see how the habit of feeding by mutual regurgitation among the ants themselves might have led to the behavior I have been describing. Cer-

tainly the genera that have developed trophallaxis among the adult members of their colonies are the very ones which most assiduously attend the Phytophthora. And it is equally certain that the latter habit is very ancient, because it was already established among the ants of the Baltic Amber during Lower Oligocene times and that, as we have seen, was many million years ago.

The dairying habit has led to an interesting specialization in certain species known as "honey ants," which inhabit desert regions or those with long, dry summers. These ants have found it very advantageous to store the honey dew collected during periods of active plant growth, and as they are unable to make cells like those of wasps and bees, have hit upon the ingenious device of using the crops of certain workers or soldiers for the purpose. In all ants, as we have seen, the crop is a capacious sac, but in the typical honey ants it becomes capable of such extraordinary distention that the abdomen of the individuals that assume the rôle of animated demijohns or carboys, becomes enormously enlarged and perfectly spherical. Such "repletes" (Fig. 66) are quite unable to walk and therefore suspend themselves by their claws from the ceilings of the nest chambers. When hungry the ordinary workers stroke their heads and receive by regurgitation droplets of the honey dew with which they were filled during seasons of plenty. The condition here described, or one of less gastric distention, has been observed in desert or xerothermal ants in very widely separated regions and belonging to some nine different genera of Myrmicinæ, Formicinæ and Dolichoderinæ (Myrmecocystus and Prenolepis in the United States and Northern Mexico, Melophorus, Camponótus, Leptomyrmex and Oligomyrmex in Australia, Plagio-

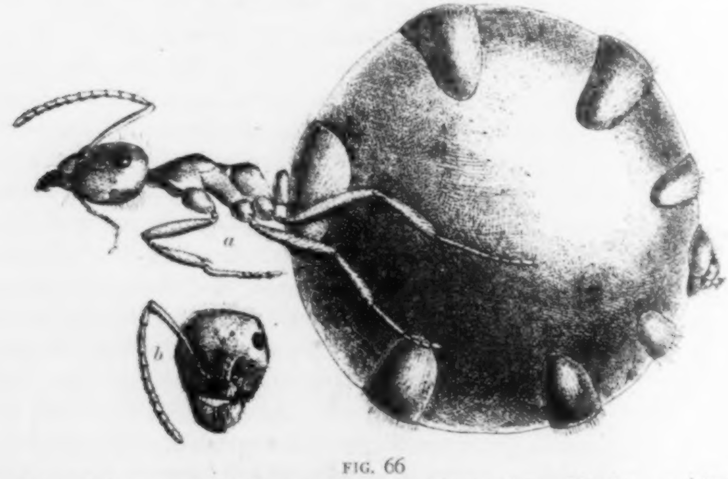

FIG. 66
Replete of honey ant (*Myrmecocystus melliger*) from Mexico. *a*, lateral aspect of insect; *b*, head from above.

lepis and Aëromyrma in Africa and Pheidole in Australia and the southwestern United States).

A more direct vegetarian adaptation is seen in many Formicidæ that inhabit the same desert or xerothermal regions as the honey ants. In such regions insect food is at no time abundant and is often so scarce that the ants are compelled to eat the seeds of the sparse herbaceous vegetation. At least a dozen genera, all Myrmicinæ, illustrate this adaptation: Pogonomyrmex, Veromessor, Novomessor and Solenopsis in America, Messor, Oxyopomyrmex, Goniomma, Tetramorium and Monomorium in the southern Palearctic region, Meranoplus in the Indoaustralian, Cratomyrmex and Ocymyrmex in the Ethiopian region and Pheidole (Fig. 57) in the warmer parts of both hemispheres. It was at one time believed that some of these ants actually sow around their nests the grasses and other herbaceous plants from which they gather the seeds, but this has been disproved. They are merely collected, husked and stored in special chambers or granaries in the more superficial and dryer parts of the formicary. Emery has shown that as food the proteids are preferred to the starchy portions of the seeds and are also fed to the larvæ. *Messor barbarus*, the ant to which Solomon refers, is one of these harvesters. Probably none of them disdains insect food when it can be had. Nevertheless the adaptation to crushing hard seeds is so pronounced in certain genera that the mandibles have become distinctly modified. Their blades have become broader and more convex and the head has been enlarged to accommodate the more powerful mandibular muscles. In certain forms (Pheidole, Messor, Novomessor, Holcomyrmex) the soldiers or major workers seem to function as the official seed-crushers of the colony.

The harvesting ants can hardly be regarded as true agriculturists because they neither sow nor cultivate the plants from which they obtain the seeds. Yet there is a group of ants which may properly be described as horticultural, namely the Attiini, a Myrmicine tribe comprising about 100 exclusively American species and ranging from Long Island, N. Y., to Argentina, though well represented by species only within the tropics. The tribe includes several genera (Cyphomyrmex, Apterostigma, Sericomyrmex, Myrmicocrypta, etc.) the species of which are small and timid and form small colonies with monomorphic workers, while others (Atta and Acromyrmex) are large and aggressive and form very populous colonies with extremely polymorphic workers. The Attas or parasol ants inhabit the savannas and forests of South and Central America, Mexico, Cuba and Texas. Their extensive excavations result in the formation of large mounds and often cover a considerable area (Fig. 67). According to Branner, a single mound of

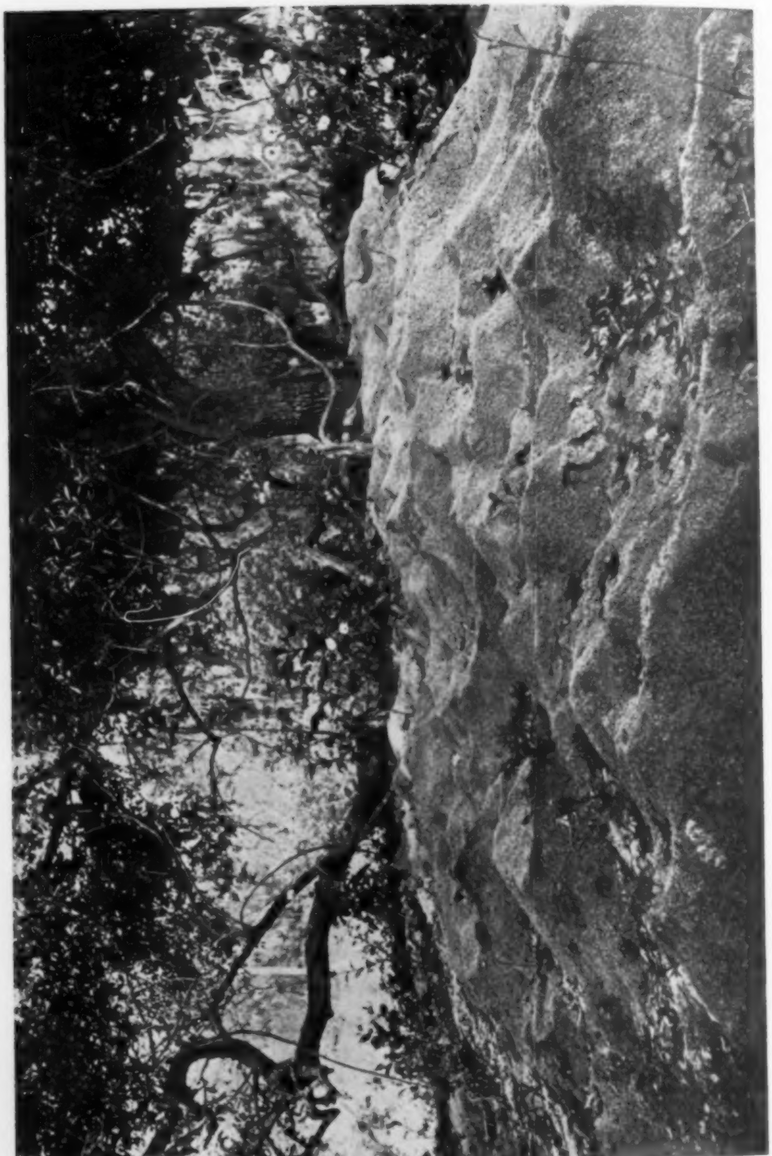

FIG. 67

Nest of the Texan leaf-cutting ant (*Atta texana*) at Victoria, Texas. (Photograph by S. J. Hunter.)

the common Brazilian *Atta sexdens* may contain as much as 265 cubic meters of earth, and the population of a colony of this species, according to Sampaio, may number from 175,000 to 600,000 individuals. Of course, the size of the mounds varies with the depth of the excavations, which are much shallower in the rain-forests than in the dry savannas. From their mounds the ants make well-worn paths through the surrounding vegetation and frequently defoliate bushes or trees, cutting large pieces out of their leaves and carrying them like banners to their nests. The pieces are then cut into smaller fragments and built up on the floors of the large nest chambers (Figs. 68 and 69) in the form of sponge-like

FIG. 68

Vertical section through the center of a nest of the Argentinian leaf cutter, *Atta vollenweideri*, showing the chambers containing the fungus gardens. (Photograph by Dr. Carlos Bruch).

masses, which become covered with a white, mould-like fungus mycelium (Figs. 70 and 71). The latter is treated in some unknown manner by the smallest, exclusively hypogæic caste of workers, so that the hyphæ produce abundant clusters of small, spherical dwellings, the bromatia (Fig. 72), which are eaten by the ants and fed to their larvæ. Each species of Attiine ant cultivates its own particular fungus and no other is permitted to grow in the nest. That the bromatia are really anomalous growths induced

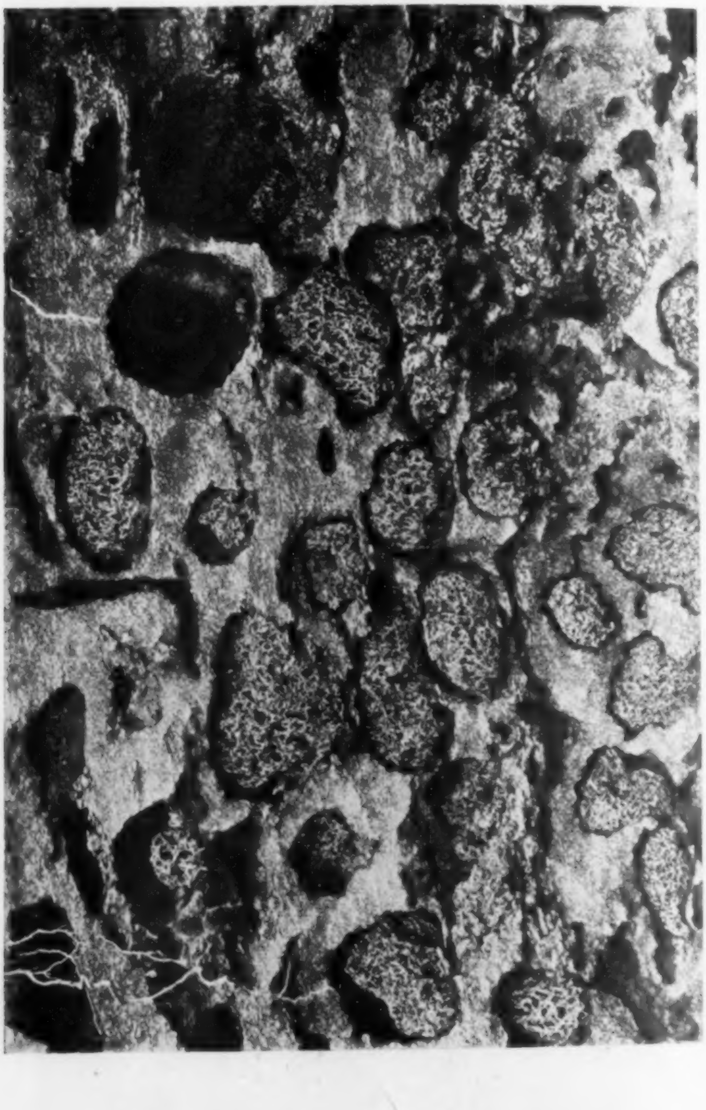

FIG. 69

Portion of nest of *Atta vollenweideri* shown in Fig. 68, more enlarged to show the sponge-like fungus-gardens *in situ* in the chambers. About one eighth natural size. (Photograph by Dr. Carlos Bruch.)

by the ants is indicated by the fact that they do not appear when the fungus is grown in isolation on artificial media. Alfred Moel-

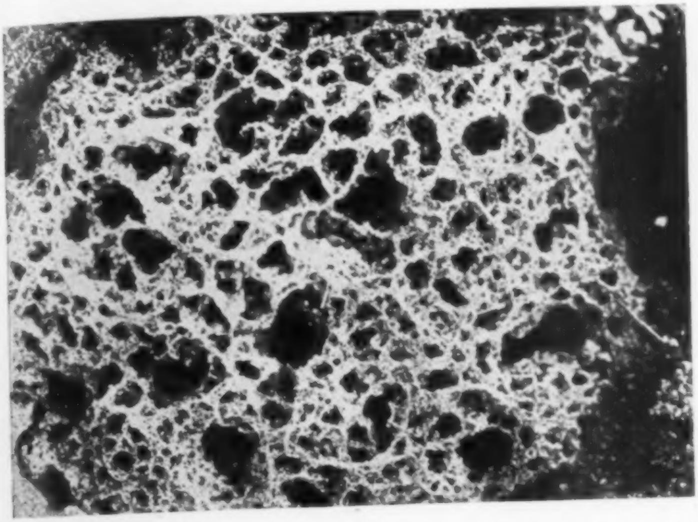

FIG. 70
Portion of fungus garden of the Texan leaf-cutting ant (*Atta texana*). About one half natural size.

FIG. 71
Fungus garden built in a Petri dish by a colony of Apterostigma in British Guiana. Natural size. (Photograph by Mr. Tee-Van.)

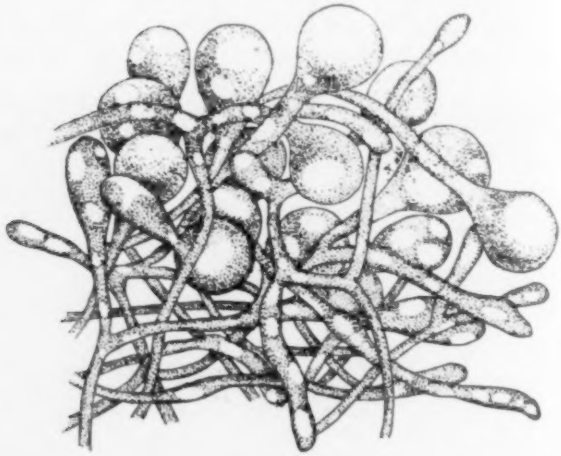

FIG. 72
Modified mycelium (bromatium) of fungus cultivated by the Argentinian *Moellerius heyeri*. The globular swellings of the hyphæ are produced by the ants. (After Carlos Bruch.)

ler, who was the first to cultivate these fungi, regarded them as belonging to the Agarics and named one of them *Rozites gongylophora*. Either the ants prevent the mushrooms from appearing, or, more probably the subterranean conditions under which the mycelium is cultivated are unfavorable to their development. Moeller was also unable to obtain the mushrooms in his cultures, but found those of Rozites growing on the surface of an abandoned Acromyrmex nest. That the fungi cultivated by the various Attiini belong to several different genera is shown by Bruch and Spegazzini who have recently been able to identify the mushrooms of the fungi cultivated by several Argentinian Attiini. *Acromyrmex lundi*, e. g. cultivates *Xylaria micrura* Speg., *Moellerius heyeri*, *Poroniopsis bruchi* Speg. and *Atta vollenweideri*, a gigantic Agaric, *Locellina Mazzuchii* Speg. (Fig. 73).

The lower genera of the Attiini differ in many particulars from such highly specialized forms as Atta and Acromyrmex. Their nests are smaller and there are differences in the gardens and the substratum, or substances on which the fungi are grown. The species of Trachymyrmex suspend the garden from the ceiling of the nest chamber instead of building it on the floor, and in some species of Apterostigma it is enclosed in a spherical envelope of dense mycelium, so that, except for its larger size, it much resembles the silken egg-case of a spider. These ants and others, such as Cyphomyrmex and Myrmicocrypta, use the excrement of other insects, especially of caterpillars, as a substratum for the gardens, and one species, *Cyphomyrmex rimosus*, cultivates a very peculiar fungus (*Tyridiomyces formicarum* Wheeler), which does not grow

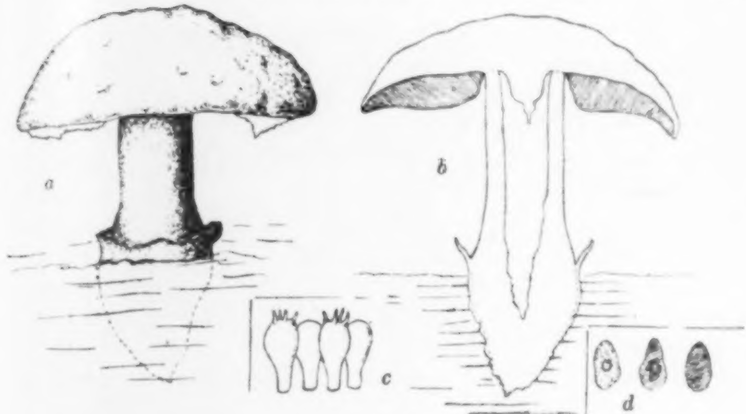

FIG. 73

a, *Locellina Mazzuchii* the gigantic fruiting phase (pileus 30 to 42 cm. in diameter!) of the fungus cultivated by the Argentinian leaf-cutting ant (*Atta vollenweideri*); *b*, section of same; *c*, basidia; *d*, spores. (After C. Speggazzini.)

in the form of a mycelium but of isolated, compact bodies, resembling little pieces of American cheese, and consisting of yeast-like cells. The same or a very similar fungus is grown by the species of Mycocepurus.

How do all these Attiine ants come into possession of the various fungi which they cultivate with such consummate skill. The question is, of course, twofold, since we should like to know how the individual colony obtains its fungus and how the ancestors of the existing Attiini first acquired the fungus-growing habit. The former question has been answered by the very interesting investigations of Sampaio, H. von Ihering, J. Huber and Goeldi on the Brazilian *Atta sexdens* and of Bruch on the Argentinian *Acromyrmex lundi*. The virgin queen of these species, before leaving the parental nest for her marriage flight, takes a good meal of fungus. The hyphæ, together with the strigil sweepings from her own body and, according to Bruch, also some particles of the substratum, are packed into her infrabuccal pocket, where they form a large pellet, which she retains till she has mated, thrown off her wings and made a small chamber for herself in the soil. She then casts the pellet on the floor of the chamber where its hyphæ begin to proliferate in the moist air and draw their nutriment from the extraneous materials with which they are mingled (Fig. 74*A*). The queen carefully watches the incipient garden and accelerates its growth by manuring it with her feces (*C* and *D*). She begins to lay eggs (Fig. 76 *A*) and even breaks up some of them and adds them to the garden, which soon becomes large enough to form a kind of nest for the intact and developing eggs (Fig. 74 *B* to *F*).

The young larvæ on hatching proceed to eat the mycelium and eventually pupate and emerge as small workers, which break through the soil, bring in pieces of leaves and add them to the garden. The care of the latter then devolves on the workers and the queen henceforth devotes herself to laying eggs. The colony is now established and its further development is merely a matter of enlarging the nest, multiplying the gardens and increasing the population. Thus Atta and Acromyrmex transmit their food-plants from generation to generation in a very simple manner, that is, merely by the queen's retaining, till she has established her nest chamber, the infrabuccal pellet consisting of her last meal in the colony in which she was reared. And there is every reason

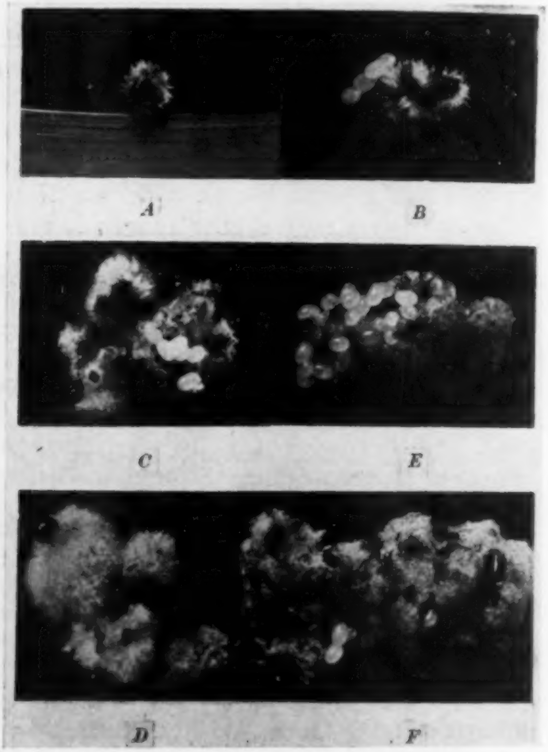

FIG. 74

Stages in the development of the fungus garden by the queen of the Argentinian *Moellerius hyeri*. *A*, pellet of substratum 36 hours after its ejection from the queen's infrabuccal pocket. The hyphæ have begun to grow. *B*, same pellet after 3 days, with 4 eggs; *C*, same pellet after 8 days, showing droplets of feces with which the queen manures the hyphæ. *D*, same pellet after 12 days, also showing droplets of feces; *E*, small fungus garden after 30 days, with 32 eggs; *F*, same after 40 days. The magnification of all the figures is very nearly 10 diameters. (Photographs by Dr. Carlos Bruch.)

FIG. 75
A, an infrabuccal pellet of the queen *Moellerius heyeri* after cultivation for 36 hours on gelatine. X10. *B*, eggs and pellets made of filter paper by a queen *Moellerius heyeri* that had failed to develop a fungus garden. X10. (Photograph by Dr. Carlos Bruch.)

to suppose that the same method of transmitting the fungus from the maternal to the daughter colonies is practiced by all the other genera of the tribe.

Of course, the answer to the question as to how the ancestors of the Attiini acquired their food-fungi in the first place must be purely conjectural. Yet certain observation by Professor I. W. Bailey and myself seem to indicate from what simple beginnings the elaborate fungus-growing habits may have been evolved. An examination of the infrabuccal pellets of the most diverse ants shows that in nearly every case they contain fungus spores or pieces of mycelium collected from the surfaces of their bodies or from the walls of the nest. Moreover, many ants have a habit of casting their pellets on the refuse heaps, or kitchen-middens of their nests, and Professor Bailey finds that in the case of certain African

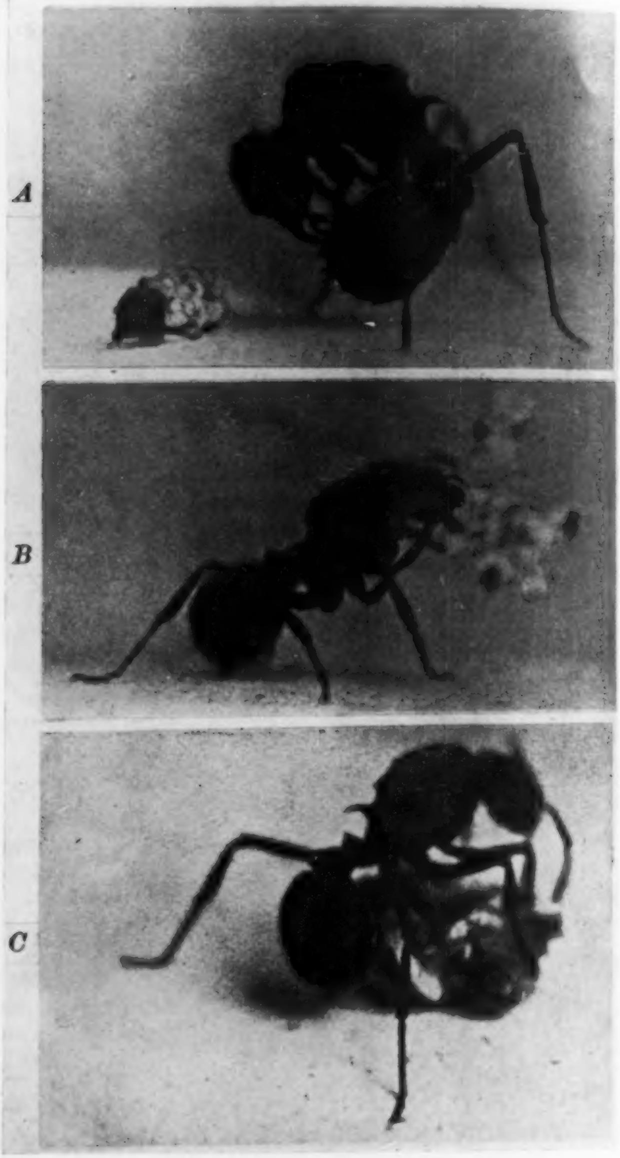

FIG. 76

Behavior of the queen of *Moellerius heyeri*. *A*, photographed in the act of laying an egg. The incipient fungus garden in which the egg will be placed is shown to the left resting on the floor of the nest chamber; *B*, queen placing an egg in the fungus garden which is sticking to the glass wall of the artificial nest. *C*, queen photographed in the act of placing a droplet of feces in the fungus garden. Magnification 5 diameters. (Photographs by Dr. Carlos Bruch.)

FIG. 77
Two friendly queens of *Moellerius heyeri* caring for a single incipient fungus garden, which is adhering to the glass wall of the artificial nest X5. (Photograph by Dr. Carlos Bruch.)

Crematogasters that live in the moist cavities of plants (Plectronia, Cuviera) the refuse heaps consist very largely of such ejected pellets and produce a luxuriant growth of aërial hyphæ which are cropped by the ants. From such a condition it is, perhaps, only a short step to the establishment of small gardens consisting at first of the pellets and later of these and accumulations of extraneous materials, such as the feces of the ants, those of caterpillars and beetles, vegetable detritus, etc., which might serve to enlarge the substratum and increase the growth of the fungus. The selection of particular species of fungi and their careful culture and transmission are evidently specializations that must have been established before the stages represented by even the most primitive existing Attiini could have been attained.

Whatever may have been the processes whereby the ancestral Attiini developed the fungus-growing habit, it must have originated in the more humid portions of the tropics, since nearly all the more primitive species of the tribe are still confined to the rain-forests. But certain species soon found that by sinking their galleries and chambers to a greater depth in the soil they could easily carry on their fungus farming even in arid regions. Thus some species of Moellerius, Trachymyrmex and Cyphomyrmex have come to live in the dry deserts of Arizona, New Mexico and northern Mexico, and as they can always find in such localities enough vegetable material for the substrata of their gardens, they have attained to a control of their environment and food-supply, which even the human inhabitants of those regions might envy.

THE MARINE FISHERIES, THE STATE AND THE BIOLOGIST

By WILL F. THOMPSON

MANY of the great marine fisheries of the world lie within the jurisdiction of more than a single sovereign country. The great North Sea fisheries, those of the Grand Banks, the salmon fisheries of the Fraser River (now nearly extinct), and the halibut fisheries of the North Pacific might be cited as examples. It would seem that this divided ownership has reacted most disastrously upon their care. Responsibility seems in such cases to be simply lost, not divided, and the net effect is that no one cares to sacrifice his own interests to maintain the fishery for the benefit of all. The splendid scientific work done in the North Sea contrasts vividly with the relative futility of the movement to conserve the vanishing bottom fisheries there by regulatory laws. There is simply no machinery capable of overriding the selfish interests of the few in each country, supplemented as it always is by the general suspicion one nation seems to think it necessary to have of every other nation.

The case seems far more hopeful, where there is no division of authority. And in many of our great states fisheries exist which are entirely under the legal control of a single state government. That is true in California, where there is not a single fishery common to both its own water and the waters of another state or country save of the sparsely inhabited desert of Lower California, to whose less exploited fisheries vessels often go from Southern California ports. There is thus no possibility of shirking responsibility—the care of its fisheries devolves upon California alone by virtue of the Constitution of the United States and of its geographical position. No question of nationalism can be involved, only that of sectionalism. As a result, the failure to conserve the fisheries for the people of the entire state can result only from faulty organization of public opinion and the lack of real proof of the necessity of conservation.

The securing of this proof of the condition of the fisheries has in California, as everywhere else, been recognized as a legitimate function of the responsible government, and *the proper execution of that function is vital to the success of any popular movement toward conservation.* Unlike the forests and the mines, private ownership has never been granted in the fisheries, save in the case

of oysters and those of certain fresh waters, and for that reason aroused popular opinion is entirely likely to control in the end. But powerful interests have grown up who will vigorously object to curtailment of their activities. Something tantamount to legal proof is necessary before what seems to them confiscation may be indulged in. And they have in the past shown a vitality which augurs ill for any but well-based movements toward conservation.

The general policy of conservation is, moreover, largely supported by men among the public who are not trained scientists and do not know the value of evidence. Their conclusions as to the existence of depletion may carry weight where, as in the case of birds and mammals, any honest man may observe conditions with his own eyes, and where powerful interests are not placed in jeopardy. But in the marine fisheries this is not true, for the fish are not easily observed and the evidence must come from statistical proof of comprehensive character. Under such circumstances the cry of conservation, raised hysterically and hastily, as is done even by scientists at times, must in the long run lead to failure and the injury of the cause at stake. And measures of regulation or restriction passed in response to pleas made on an insecure basis must in the end fail to justify themselves. So the acquirement of real knowledge, while a protection to the men legitimately engaged in exploitation, is equally such to the cause of conservation itself, for it should not only prevent this lack of balance and undue regulation, but it should prevent the growth of interests which must later be curtailed.

This necessity of knowledge was acknowledged by the fishery authorities of the State of California when they instituted the present system of observing the fisheries. Their action in this regard was based on the following facts: First, that enough accurate knowledge already exists to prove the susceptibility of marine fisheries in general to overfishing; second, that proof is required in the case of each individual fishery, and that there is no way of knowing the strain a species will stand save by submitting it to one; third, that such a course of action implies the duty of the state to maintain a constant and intelligent ward over its fisheries; and finally, that such a ward is possible and that it implies continuous and prolonged statistical and biological investigations.

In regard to the first point, the existence of proof that marine fisheries are exhaustible, we must turn to the oldest and best known of fisheries, namely those in North European seas. Contrary to the opinions of many, these great fisheries cannot justifiably be called ancient. The use of steam vessels began in 1880; the otter trawl first came into use in 1895, laying open to exploitation the depths of the ocean below fifty fathoms; while the means of mar-

keting and the extent of the demand increased equally with the recent great industrial expansion. The latter involved the development of railroads, the refrigeration of food products, the use of cans for their preservation, fast steamships to carry them, the growth of city life as a market, etc. Meanwhile, as cited by Jenkins ("The Sea Fisheries," 1920) as an illustration of the trend of the times, the number of fishing vessels in the port of Aberdeen, Scotland, increased 258 per cent. in the period 1897-1903, and according to the estimate of the same authority, agreeing with that of others, the efficiency of each steam trawler of to-day exceeds eight times that of the sailing trawler it displaced (aside from the independence the steamer has of weather and distance). The fisheries in other parts of the world are still more recent, and show the same great increase in apparatus although not necessarily in catch. If these facts are considered, it is impossible to doubt that, unless civilization comes to an abrupt pause, with the destruction of our highly developed transportation and of our industrialism which builds towns and markets, we are on the brink of an era of exploitation of our fisheries, and not at the crest of such an era. And the existence of overfishing now becomes a serious problem, for if the fisheries do show depletion, it is indeed a serious question whether they will, even in their more stable parts, survive the coming strain. Faith in our destiny and that of the world implies care of our resources of fish.

That they do show depletion in certain fisheries is now proved. The most clearly ascertained instances at present are those of the bottom fisheries. Thus the halibut in both the Atlantic and the Pacific has decreased with great rapidity. But the bottom fisheries of the North Sea for plaice and other allied species are, as Garstang ("The Impoverishment of the Sea," 1900) says, "not only exhaustible, but in rapid and continuous process of exhaustion." This conclusion has been seconded and supported by men who have, in the various countries around the North Sea, actually had the examination of the statistics in their care, as Heincke, Fulton, Thompson and others, such as Jenkins and Allen. And if these bottom fisheries already show exhaustion, since they are more stationary, are most highly valued, and were first sought for, it is not to be expected that "pelagic" fish will show otherwise upon the imposition of greater strain, even though they are more abundant. But in this connection, it must, indeed, be remembered that there is no accurate means of determining whether pelagic fish actually are more abundant than other fish in the ocean—although we do know that the cod and the herring, for instance, are not numberless, as some estimates have made them.

Against such a view there has been urged the objection that

the fisheries seem to be prospering and to be continuing on a firm basis. That fact may be granted, however, without conflicting with the above conclusions. It may be admitted that the total yield of the fisheries does not everywhere seem to decline, but it can be proved that continuously greater toil is required to obtain it. That this decreasing yield for the effort involved does not attract more attention should be understandable when it is considered that the cost of catching fish is but a fraction of the cost of distribution. Thus the fisherman may receive eight cents per pound where the retailer asks forty cents, and doubling the fisherman's price would add but a fifth to the retailer's price. The cost of obtaining the fish could be multiplied many fold without seriously affecting the final price to the consumer. The latter is, moreover, willing to pay high prices for a product to which he has become accustomed, and the rarer it is the more he will pay. The increase in initial cost does not seem, in fact, to be of the greatest importance.

There is also this fact to be taken into consideration, that there are influences which actually counteract the effect of increasing scarcity in raising the initial cost. The accompaniments of that intensified exploitation which results in depletion are the constant broadening of the fishing grounds, the inclusion of more than one species of fish and of inferior quality in the catch of the boats, the development of means of preservation, the constant improvement of gear and the increase in quantity of apparatus. All these things tend to eliminate the great and sudden fluctuations in amount of yield which are characteristic of fisheries confined to one species or one locality. These variations in yield render the exploitation of the fisheries expensive and uncertain because the periods of abundance must be made to pay interest upon the capital and to maintain the organization during periods of scarcity. Their elimination as a result of intense fishing undoubtedly does reduce the cost of fish to the consumer, perhaps to the extent that for a while the influence of depletion in raising the initial cost will not be felt.

But in the end that very fact may defeat the natural safeguard which should protect a species, namely, the lack of profit in carrying on a fishery when it comes dangerously near to exhaustion. It becomes possible to prolong a fishery because other species are taken; the by-product becomes the mainstay of the business and the depleted species is kept under a strain for which it could not itself pay. If it were not for cod, perhaps the halibut fishery of Iceland might have long since collapsed; and if it were not for the cheaper round fishes, the flat fishes in the North Sea might be pursued far less rigorously. On the Pacific coast, the tuna and sardine

fishery of California may have been of considerable assistance to the albacore fishery. In fact, the objection often raised to the possibility of over-fishing that the fisheries are prospering and that they would immediately cease to prosper should depletion occur is not a valid one. But that they would ultimately fail as a result of over-fishing seems sure.

Another basis for scepticism as to the reality of the fact of possible exhaustion has been the seeming boundlessness of the sea and its resources. But every fisherman knows that the areas within which fish of a given species are found are very limited, perhaps less so in the cases of "pelagic" fishes than in those of "demersal," yet highly limited nevertheless. And the scientist will testify to the sharp limitations which temperature, depth, salinity and currents place upon every species, so that it is in reality only a very small part of the ocean which yields our commercial fishes. They are, in fact, limited largely to the area of the coastal regions or the continental shelf, where there is drainage from the land, and to comparatively small parts of that shelf. In so far as this productive area is concerned, Gran and others have remarked that it corresponds in general with the distribution of the minute plankton organisms which are vastly more abundant where coastal water is found; and upon these plankton organisms fish must necessarily exist in the final analysis. And even where conditions are thus favorable, and the fisheries are highly developed, as in the North Sea, Allen ("Food from the Sea," 1917) estimates that an acre yields but fifteen pounds of fish per year while pasture land yields seventy-three pounds of beef. In accordance with these facts the experiments which have been made in marking fish and observing the frequency of recapture have shown that the fishermen are able to take, and do take, a very high percentage of the bottom fish in the North Sea. What they do with other fish, such as the herring and the sardine, or in any other regions, is for the most part unknown. It is therefore a mistake to assume that the resources of the sea are inexhaustible, or that over-fishing characterizes small areas easily replenished from without.

There is, indeed, no manner of gauging in advance the productivity of the ocean, in so far as edible fish are concerned. It is in the first place obvious to students of the matter that the amount of food present for fishes does not determine abundance, any more than the amount of grass did determine the abundance of the buffalo on our plains, or of deer in our forests. But it is certain that the rate of reproduction varies widely, and with it the relative resistance to depletion of the species of fish. Such matters as egg production, length of life, varying mortality at different stages and time of sexual maturity must all be taken into account, together

with the sharp limitations provided by climatic and geographical conditions. Moreover, the relative amount of competition for the available food is unknown, although we do know that the commercial fishes are probably but a small part of the population to be supported by the sea. And even if the abundance of the species were a gauge to its resistance to a strain—which it does not necessarily have to be—there is thus far no method of accurately ascertaining the abundance of any one species of fish or of all together save within limited areas of the ocean. It seems, indeed, that there is no method of measuring the amount of fishing a species will stand save by submitting it to a strain.

The only hint which can be obtained concerning the limits of the fisheries in California come from a comparison of the productive area with that of the North Sea, where the bottom fisheries show decline. It is, however, very hard to define the productive area, save by the width of the continental shelf. The area within the one hundred fathom line in the North Sea is approximately 130,000 squares miles (nautical), while off the coast of California it is about 7,500 square miles. In the former case this area is about 300 miles wide and 450 long, but in California the average width is but 8.4 miles, much of this rocky or unsuitable for bottom fishes. In this connection it must be recollected that, as cited above, Gran and other authorities regard the presence of coastal water with land drainage in it as essential to the production of abundant planktonic life. Such water is abundant off the coast of Europe, but the California coast is more arid in nature, especially the southern portion. However, the great fisheries of California are of the "pelagic" type, regarding which such speculation may be limited in value. Nevertheless, it is probably safe to say, when all is taken into consideration, that these fisheries are far more limited in proportion to length of coast line than is the case in the North Sea, and hence much more susceptible to overfishing.

As has been said above, the possibility and actuality of overfishing have been definitely proved, yet it seems true that there is no arbitrary limit which can be economically assigned to any fishery. It would be indeed sheer waste to impose a limit below what might be safely taken and the alternative is plain, to allow the imposition of all the strain the species will carry. It is, as a matter of fact, the only politically practical course of action, at the same time being the correct one from the scientific standpoint.

But it must not be forgotten that the acceptance of such a fact implies the serious duty of close observation and prompt action, in case of overfishing, by the government in control. That is

clearly recognized by the fishery authorities of California and is the mainspring of their actions.

These things having been recognized as true, it followed that a careful survey of measures necessary for such observations was in order, and this has been made in so far as possible. For such purposes the great mass of literature published by the various countries around the North Sea was available, especially that issued by the "Conseil Permanent International pour l'Exploration de la Mer," or inspired by it. It soon became evident that it was impossible for the State of California to undertake the many lines of general inquiry into the varying conditions of the sea and its life which had been investigated more or less by these European countries. That would have been tunnelling the mountain by removing it in its entirety. It was necessary for the state to limit its efforts to those fields which had been shown to bear directly on the ascertainment of the condition of the fisheries; namely, the measurement of the variance in abundance of the fishes in the sea, the effects of fishing upon it and the biological criteria of overfishing. A careful perusal of much of the hydrographic and planktonic work demonstrated its remoteness from the work in hand despite its undoubtedly great ultimate value, and showed that most of the immediate questions could be solved to the required degree without their aid. There were necessary certain biological studies upon the fishes themselves, but above all a statistical study of the fisheries and the fish.

This method of approach, as Johan Hjort has most appropriately said of a certain phase of it, is regarding the study of the fisheries in a similar light to the study of the vital statistics of mankind. It involves primarily the taking of what amounts to a comparative census from year to year in order to test the relative abundance—not the actual abundance—of fish; then to determine whether such great fluctuations as appear are due to natural causes or to overfishing.

For this program, the legislature of the state has passed laws taxing the fisheries industries fifty cents per ton of raw fish used for canning, and has definitely specified the duty of the agents of the state. It is unnecessary to give the details of these laws, but something as to their operation will be of use.

Every commercial transaction involving the first sale of fish is accompanied by the giving of a receipt by the buyer upon a form issued by the fish and game commission and of this receipt one copy is returned to the commission and another kept by the dealer. There are, therefore, actual records of all fish taken for profit, according to the boat and to the day. This unique system has been most successful in its operation for the last three years, avoiding

what we now know were widely erroneous estimates in statistics; while the fresh fish dealer has frequently for the first time a record of his own dealings. The results obtained have continuity, and are in such detail that market conditions, changes in apparatus or fishing fleets, etc., may be readily discounted. So every commercial fishing boat becomes in effect a means of testing the abundance of fish, and it is possible to segregate the effects of scarcity of fish from the effects of those economic changes which alter the total yield. This appears the necessary procedure from the experience of investigators in the North Sea, and is preferable to the limited experimental fishing which is possible. We do, in fact, feel confident that we will have a relatively accurate and sensitive record of the variations in abundance of fish in the ocean, when studied in connection with biological facts.

This scientific collection of statistics is the starting point and the foundation for further investigations. The interpretation of the evidence drawn therefrom is the duty of the biologists engaged by the commission; for the great fluctuations in abundance of fish which may be shown must be analyzed and their true nature discovered. Such natural fluctuations are very likely to be mistaken for depletion from overfishing; or, perhaps, if of opposite trend, as a contradiction of any theory of overfishing when they are in truth, as we have said, due to natural causes, and depletion may exist despite the temporary obliteration of the evidence. There must, as a consequence, be developed and utilized those biological criteria which distinguish depletion due to excessive fishing. The biological knowledge necessary for the use and formulation of such criteria includes among other things the determination of age, the discovery of migrations and in so far as possible the correlation of abundance with natural physical conditions. One may justifiably call it ecology on a vast scale. Granted a fair knowledge of these criteria, it is not exceeding the reasonable to hope that the fishery authorities will be able to give warning when depletion is occurring—and, indeed, unless a degree of confidence can be placed in the competency of the work, the exploitation of the fisheries should not be allowed to proceed freely, nor can freedom be had from the constant fear of ruthless exploitation.

There is, in addition, a need on the part of legislators for competent data upon which measures of regulation may be based. The imposition of arbitrary and reckless restrictions should be prevented by the acquisition of proper knowledge as soon as possible. At present many of our fishery laws are untenable from a scientific standpoint, save in so far as they actually operate to reduce the take. And even if it be said that legislatures will not take proper action, it would be a defeatist's attitude to take to

fail to provide them proper knowledge upon which they might take action. There are a great many legislators who will act along the line of their best knowledge, and more who will respond to intelligent pressure on the part of the public.

In thus accepting conservation as a major policy because of its dependence upon the legal powers of the state, the program adopted in California has not been oblivious of the fact that the work for that purpose has a very definite bearing upon some of the greatest problems of exploitation. As an example, the abundance of fish is subject to great natural fluctuations beyond the control of man. The return from the fisheries vary greatly from day to day, from season to season, and from year to year. The resultant waste is an exaggerated case of the same kind which the electrical engineer meets when he is faced with the "peak load" or maximum use of electricity during a short period each day. Just as apparatus must be available to carry this "peak load," so must the fish canners or dealers maintain the machinery and organization for brief periods of maximum supply and longer ones of scarcity as well as variations in demand which are disconcerting both to the dealers and consumers. The meat packers, their rivals, need not do this. The understanding of these fluctuations so that regularly recurring ones may be expected, others foretold and provision made to meet or avoid them, is without doubt one of the most neglected functions of government scientists. The proper study of depletion necessitates just such an understanding of these changes as will serve the industry.

It must be acknowledged that in adopting such a program, installing such a system of statistics and founding a California state fisheries laboratory at San Pedro to care for the biological science of the subject, the state of California is experimenting. It still remains to be seen whether popular support will be rendered the project, either on the part of scientific men or the general public. The field seems to be one in which the scientist, particularly the biologist, should welcome a chance to show how his work can be applied to the needs of humanity; but, aside from this, basic principles of animal life and behavior are really involved to such an extent as to satisfy the most academic of men and are attacked with the aid of vast masses of material unobtainable through any other source than the commercial fisheries. On the part of the public, it would seem that only a failure to understand or lack of faith in the competency of the work could lead to lack of support.

It is sincerely to be hoped that this effort to approach the problems of conservation upon a rational and well-balanced basis will meet with the reception its sincerity deserves.

DE ANOPLURIS

By Professor G. F. FERRIS
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THE distinguished professor had attained some portion of his distinction by reason of years of work spent upon a small and little studied group of insects. His wife and small daughter chanced into his laboratory one day and discovered a student examining one of these insects through a microscope. The small daughter demanded a look and then came the inevitable question, "What is that?"

"That," said the unsophisticated student, "is a louse."

There was a moment of pained silence and then came the gentle but unmistakable rebuke from the professor's wife, "We always call them Anoplura."

Now these very insects are the subject of my present discourse and lest I again offend the delicate sensibilities of any one I have disguised my intentions by a title to which not even the most fastidious should be able to take exception. To be sure it means the same thing as something else that might have been used, but after all there *is* something in the name by which a thing is called. Even the scratching soldier, from whom one would least expect any delicacy in such matters, conceals the identity of these insects under the euphemistic titles of "seam squirrels" and "cooties." That the deference thus accorded them reduces in the slightest degree the frequency or the painfulness of their attentions may be doubted, but at least the victim is enabled thereby to retain a bit more of the shreds of his self-respect.

In fact under the name of "cooties" these insects may quite properly become a subject even of parlor conversation. The word carries a faintly humorous connotation. One may without risk of immediate social ostracism speak of the great wads of hair that girls wear over their ears as "cootie coops." True, such an expression might not be looked upon with favor in the most refined circles, but we need only reflect upon what would happen were the wording changed a bit to see what a concession has been gained for it to be used at all.

It is perhaps a fortunate thing that this has happened, for even entomologists, who should have put all squeamishness behind them, have been more or less reticent in speaking of these particular

insects. The remark of an author writing in 1842 that "in the progress of this work, however, the author has had to contend with repeated rebukes from his fellows for entering upon the illustration of a tribe of insects whose very name was sufficient to create feelings of disgust" might almost be justified to-day. In fact, in a rather recent entomological book it is said that "from their habits lice are not popular insects even for entomologists to take up," and certainly the amount of attention they have received has never been large.

Yet I confess to being a student of these insects and I do so without hesitation and without apologies. Not to me are they merely "disgusting parasites." Not to me is the term "louse man," with which my botanical and chemical and even entomological acquaintances, with a misguided sense of humor, see fit to address me, a term of reproach. For, know you, there are very few who can merit it, scarcely more than half a dozen men in all the world in fact. To us it is a title of distinction, an evidence that we few have been able to avoid the well-beaten paths of the butterfly and beetle hunters and strike out into a but little explored country. For us it is a country of much interest and—dare I say it?—even of some beauty. And it is my hope that in these pages I may lead others to see in these disgusting parasites, these cooties, some of the things that we, their devotees, are able to see.

For a proper understanding of these parasites, these lice, as I shall not hesitate henceforth to call them, it should be explained that there are really two quite different sorts of them. One sort, known as the bird lice or the biting lice, is found chiefly on birds, although there are a few species on mammals, while all the species of the other sort, the sucking lice, occur on mammals. There is a very great difference in the manner by which the species of these two groups obtain their food. The biting lice feed by biting off and chewing up bits of hair or feathers or skin scales while the sucking lice feed by inserting their beaks through the skin and sucking up the blood of their host. Such a difference in habit is a very important thing, for with it is most intimately bound up the matter of the potentialities of the insects for harm to the animal upon which they live.

It is now a firmly established and generally recognized fact that many of the most important diseases of man and of other animals as well are transmitted by insects. In by far the majority of cases the insects concerned are forms that live upon blood, that actually pierce the skin of the animal upon which they feed. Thus in feeding upon successive individuals these insects may transfer disease-producing organisms from one individual to another. This poten-

tiality for evil is inherent in every blood-sucking form, and its possibilities are realized to a high degree in those blood-sucking lice that live upon man, the familiar "cooties" of the war period.

Under the conditions that usually prevail in armies it is impossible for soldiers to keep themselves free from these insects. Thus it was that certain diseases which are transmitted by the lice became especially prevalent during the late war. Typhus and trench fever are transmitted by lice, and as far as known only by lice, and the measures for the control of these diseases were directed chiefly against their insect carriers. The tremendous losses due to these diseases undoubtedly had a profound effect upon the fighting strength of the various armies. Who can say to what extent the course of the war may have been influenced by them?

There are a few other diseases of man that are known to be carried by lice, and they have been suspected of carrying several others. It is known also that an epidemic disease of certain small Asiatic rodents is transmitted by the sucking louse that occurs upon these animals, and it is highly probable that there are many other cases of the same sort.

On the other hand the biting lice, although far exceeding the sucking lice in numbers of species, are not known to be the carriers of any diseases. If they are abundant upon their host they may cause injury merely by the irritation of their crawling about or by the matting of the hairs or feathers to which their eggs are glued. Otherwise they are of no concern to their host.

But however important and interesting this connection of lice with the transmission of disease may be it is not the only thing about them that is worthy of consideration. This connection with disease is simply a fact, and after all facts are not always as interesting as theories, even though they may be more important. Any one should be able to travel the plain and open road of fact, but there is more pleasure in the narrow and devious trail of theory that occasionally takes the traveler up into the high places—and threatens always to lead him into a bog from which the utmost of mental agility may not be sufficient to extricate him! The most interesting thing about lice is not these highly important facts of hygiene. It is that they may be made to yield a contribution to biological theory.

The starting point of this contribution is the fact that by far the majority of all the different species of lice, both of the biting and sucking groups, are found upon a single species of animal or at the most upon a few very closely related species. It is a curious fact that although horses and cattle and sheep have for many hundreds of years been in close contact in their stables each has re-

tained its particular kinds of lice. There are at least four species of lice upon domestic cattle, but these do not occur upon horses or sheep. There are at least three kinds upon sheep, but none of these has been taken from horses or cattle. There are at least two kinds on horses, but neither of these has been taken from cattle or sheep.

These instances may be paralleled by many others. The inference is obvious. It is evident that under normal conditions each species of louse "prefers" to feed upon a particular kind of animal. In other words it is adapted to feed upon the blood or epidermal structures of this particular host and does not find the blood or the epidermal structures of another kind of host a suitable food. Furthermore these insects are very reluctant to leave their host and even after its death may be found clinging to the hairs or feathers. Under experimental conditions lice have been fed upon animals very different from those upon which they normally live, and it is true that sometimes under natural conditions they may be found upon an animal on which they do not belong. Still this does not change the fact that usually each species of louse sticks pretty closely to a certain kind of animal, passing from one individual to another in the nest or at mating time. Thus it is that the parasites are in a way inherited by the young from their parents—heirlooms, if I may be pardoned an atrocious pun.

The next fact of interest is that the same species of louse may be found upon distinct but closely related species of birds or mammals in widely separated parts of the world. Thus we have upon the kingfisher in North America a louse that is the same as one on a kingfisher in Egypt. Another species is found upon various species of hawks throughout the world. Another is found on seals in both the Pacific and Atlantic Oceans. Another is found on ground squirrels in Siberia and in North America.

Now all these animals are so widely separated that certainly it is impossible for the louse of the African kingfisher to transfer directly to the North American kingfisher or for the louse of the Atlantic seal to transfer directly to the Pacific seal or for a transfer to take place in any one of the many other cases of this sort that might be mentioned. Then how has the parasite managed to get upon both of its widely separated hosts?

There are enough facts of this character to demand some attempt at a logical explanation. There must be a reason for them. If we remember that these parasites are normally passed down from one generation to another as a sort of racial inheritance and if we follow far enough the train of reasoning that is thus initiated we can not but conclude that at some time this African kingfisher

and the North American kingfisher, or the North American ground squirrel and the Siberian ground squirrel, or the members of any such pairs as we may name, were together as a single species. We have a set of facts that can not reasonably be explained unless we accept the theory of evolution. The conclusion is inevitable that at some time these kingfishers, or whatever they may be, had a common ancestor and that the shifting of land masses or climates or some other cause has left part of the descendants in one corner of the world and some in another and that there by various evolutionary processes they have become sufficiently different to be recognizable as different species.

One of the most remarkable examples of the working out of such a change is that of the llama and the camel. The paleontologists tell us that at one time there were many more species of camels and camel-like animals than there are now and that these animals first appeared in the New World. At the present time, however, the only remaining representatives of this group are the llamas of South America and the camels of Asia and Africa. Yet, separated by half the world—these cousins, or forty-second cousins, still show their relationship and their common ancestry not only in their bodily structure but in their parasites as well, for on both there is found the same species of louse.

We can extend the list of facts much farther and still the answer of common ancestry is the only reasonable explanation of them. The louse of the domestic hog has its nearest relative in the bush pigs of Africa. The lice of one kind of squirrel are more closely related to those of other squirrels than they are to the lice of other animals. The lice of the domestic chicken have their nearest relatives in the many different species of lice upon the other chicken-like birds.

Like nearly all theories, however, this one must allow for certain exceptions. We can lay down a general rule but it is almost too much to expect it to work always, at least if we are dealing with such things as living organisms. It is one of the difficulties in the way of the study of living things that they refuse to stay put. They simply will not go always into the little pigeon holes that we block out for them. Like men they must at times assert their individuality by breaking our trifling little laws; they at times demand the right of living their own lives in their own way. In some instances related species of lice are found upon animals that are certainly not very closely related and sometimes different species of lice are found on animals that really ought to have the same kind. So it must simply be admitted that in some cases other influences have been at work. Still the broad facts remain as I have pictured them.

All this leads finally and directly to the question, "What about the lice of man?" And here the evolutionist may rub his hands together in satisfaction. For here—in the most interesting place of all—the theory works! The lice of man do indeed find their nearest relatives in the lice of the apes and monkeys. In fact, it is even possible that lice of some of the apes are really the same species that occurs on man. Nor can the argument that here we are probably dealing with one of those exceptions that I have mentioned hold, for the facts throughout are entirely too consistent with each other.

So the evolutionist who, heedless of the fair name of his species, would derive man from some ape-like ancestor finds here another bit of support for his theories. He finds another stone for the defending wall that piece by piece has been built about them. Nor will this wall, like the walls of Jericho, crumble before the blasts of its enemies' trumpets. Not even before the most silver tongued of them.

I would like to close this with a moral, but morals have gone out of fashion and then it is obvious enough, anyway.

TOPOGRAPHICAL MAPS OF THE UNITED STATES

By Professor WILLIAM MORRIS DAVIS
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THE United States Geological Survey is still engaged in preparing a topographic map of our country. Progress thus far made is summarized on a large two-sheet map of the United States, on a scale of 1:240,000 or 40 miles to an inch, which serves as an index for all the quadrangles surveyed and published up to 1921; but, as a matter of fact, there are large areas in certain western states which are here marked off as surveyed, but which are represented only by maps published nearly 40 years ago, on so small a scale and of such inferior workmanship that their areas must soon be surveyed again more worthily. The contrast between the vague, sketchy contours of those early maps and the minutely intricate and apparently accurate contours of the newer maps marks the advance in topographic standards during the interval of nearly half a century.

But Americans as a rule are still topographically uneducated. They are accustomed to "flat" maps, on which the form of the land surface, the "relief" as it is technically called, is either not represented at all, or else so badly represented that it might better remain unrepresented. Automobilists are coming to know something of the ascents and descents on the roads that they follow; but most of them are still so inexperienced in or distracted from the observation of the landscape that they do not look at it closely or attentively; and even if they do, they hardly see what they look at. The driver of a car of course should not be expected to turn his attention far to the right or left; but his fellow travellers may do so, and they would be greatly aided in seeing the country they traverse by carrying along the topographic maps of their route. The cost of the maps is very low; an inquiry addressed to the director of the U. S. Geological Survey at Washington will bring information concerning maps published for any desired part of the country.

If distance lends enchantment to some views, appreciation lends enjoyment to many others, and appreciations of landscape views is greatly increased by the possession of a good map. As examples

of the contrasts between different parts of the country, look at the map of the Brasua Lake quadrangle, next west of Moosehead lake in Maine, where the brooks, many of them called "streams," have a well-defined flow only in their steep descents from the uplands, while in the lower lands they are for the most part either delayed in swamps or stopped in lakes; or of the Williamsport quadrangle, Pennsylvania, where the drainage is so well developed that neither lake nor swamp is to be found, and where the single or double ridges, running in the zigzag pattern of the Alleghenies, prevail with occasional enclosed limestone valleys, of which Nippenose is a perfect type; or of the Rives Junction quadrangle, Michigan, where the surface is agitated in the minute inequalities of morainic topography with many kettles and ponds; or of the Craig quadrangle, Missouri-Nebraska, where the boundary between the state of Missouri and Nebraska follows a former course of the Missouri river, which has now changed its channel to the right or left, thus inconveniently leaving patches of each state on the wrong side of the river; or of the Natchez quadrangle, where the uplands east of the Mississippi are cut into a labyrinth of intricately branching ravines as they fall off to the broad flood plain in which the great river swings in large meanders; or of La Sal Vieja quadrangle on the coastal plain of Texas, where the smooth surface has no valleys and very few hills, but is pitted by countless depressions, small and large, holding wet or dry lakes. The variety of topography is infinite; the lover of mountain and valley, of forest and stream will find no end of enjoyment in striving to apprehend its many expressions.

None of the maps are more remarkable than those which represent the slopes of the great volcanic island of Hawaii. Several of these have already been published, and four more soon to be completed are now issued as "advance sheets, subject to correction," on a scale of 1:31,680 with 10-foot contours incompletely drawn. Two of these sheets include parts of the Kau Forest Reserve and a stretch of the Volcano Road that leads from Hilo on the east coast southwestward to the cauldron of Kilauea. All these sheets reveal admirably the long continuity of the gradual slope by which the volcano descends from its great height, the minute ravines incised with sub-parallel courses down the slope, the occasional ragged lava surfaces where the contours are given a minutely serrate pattern, the occasional oblique or radial scarps which seem to indicate fractures and displacements in the huge mass, and most striking of all a vast bulging or convex slope, skirted around its southeastern base by the Volcano Road, which contradicts the general idea that volcanic slopes are concave. If these sheets are

continued so that, when mounted together, they may include a large share of the island, they will afford an unequaled illustration of volcanic topography on a large scale.

One of the several ways in which the newer maps are improved over the earlier ones is in the addition of submarine contours, with the same vertical intervals as those on the land, for quadrangles on the ocean and lake coasts. Thus the Cape San Martin quadrangle, California, shows the bold slopes of the Santa Lucia range, which descends to the Pacific with crowded 50-foot contour lines, to be adjoined by a gently inclined sea-floor plain with wide-spaced 50-foot contour lines across a breadth of from two to four miles off shore, before a moderate slope to deeper water begins. In strong contrast therewith, the Portsmouth quadrangle shows the sea bottom off the coast of New Hampshire and Maine to be almost as undulating as the land, although, perhaps because soundings are scattered, the texture of the submarine undulations is drawn in a coarser pattern than that of the terrestrial surface. The manifest reason for the contrast between these samples of Pacific and Atlantic borders is that the shallow sea bottom along the California coast has been uninterruptedly subjected to normal marine agencies —waves and currents—by which land-derived detritus is smoothly distributed; while the sea bottom near the New England coast has been recently, as the earth counts time, subjected to glaciation.

Another novelty on the recent maps is the addition of the numbers and subdivisions of the rectangles, over 900 in all, into which the whole country has been divided by the War Department. These rectangles measure one degree of latitude on the sides and one degree of longitude at the top and bottom; they are numbered from north to south in successive columns, beginning on the Pacific coast. Each rectangle is divided into north and south halves; and each half into four quarters (I, northwest; II, northeast; III, southwest; IV, southeast). Thus the Conejos, Colo., quadrangle of the Geological Survey nomenclature, on a scale of 1:96,000, is the 298-S-II & IV quadrangle of the War Department. When the scale is large, the numerical nomenclature is somewhat unhandy; thus the Firebaugh, Calif., quadrangle of the Survey on a scale of 1:31,680, is the 60-N-II-W/2-SW/4 quadrangle of the War Department.

Outline maps of the states have been called for and prepared in recent years on a scale of 1:500,000. All are now completed, except that Nevada, Utah, Colorado and New Mexico are in press, and Texas is yet to be drawn. These maps will doubtless be issued eventually with contours, but for the present the map of such a state as South Dakota shows only its rivers and streams, many of

which are printed in broken lines to show their intermittent flow, its railroads, its county and village names, and its township and section rectangles as marked off years ago by the Land-Survey preliminary to selling the public lands. Many of our state maps in the central and western parts of the country are based on those crude surveys, which served their purpose well enough when they were honestly made in plain country, but in rough country the case was different. One of the recently issued Geological Survey maps of a quadrangle in a mountainous state explains in a legend at the bottom of the sheet that the township and sectional rectangles of the Land Survey for a part of the area are omitted "because land plats and topography can not be reconciled and no [section] corners can be found." This recalls a story of early days in California, told by the late Professor Brewer of Yale, who was in the 60's a member of the California Geological Survey. A desperado, at last captured after many deeds of violence, was about to be hanged by a vigilance committee. When asked if he had anything on his mind which he wished to confess, he said he had; but it was not his manifold murders that troubled him. The only misdeeds to which he owned up with remorse had been committed while he was an assistant on the Land Survey; the law required that the corners of the square-mile sections should be marked with wooden posts, charred at one end and driven into the ground; the desperado confessed that, in a district where wood was scarce, he had marked the section corners with burnt matches. We are only about half-a-century climb up from that rung in the ladder of our civilization. One of the most characteristic signs of our ascent to a higher level is the preparation of a large number of excellent maps of our domain, some examples of which are noted above.

WHAT NEXT IN IMMIGRATION LEGISLATION?

By Professor ROBERT DE C. WARD
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THE IMPERATIVE NECESSITY OF FURTHER "PERMANENT" LEGISLATION

THE present 3 per cent. immigration restriction law will expire on June 30, 1924. What shall take its place? The conditions which led to its adoption will still exist. We are facing a permanent tendency toward rapidly increasing and steadily deteriorating immigration, and millions of prospective immigrants overseas are impatiently waiting for the thirtieth of June, 1924, when they will rush in, in a seething chaotic mob, unless Congress takes steps to stop them.

THE OPPOSITION TO RESTRICTION

To any program for restriction there is certain to be active, well-organized and heavily financed opposition. This opposition is centered in (1) certain racial groups which are interested, not in the future of America, but in the increase of their own race in America; (2) employers who want foreign labor so cheap that it is dear at any price; who put pocketbook above patriotism; (3) the steamship companies, who believe themselves to have vested rights in the United States as a dumping-ground for their human cargoes, and (4) those who have been well termed "the incurable sentimentalists." Every effort is now being made to misconstrue our present laws; to distort and misrepresent their effects; to make them unworkable and unpopular. These laws are being subjected to organized attack by "interested" individuals, alien racial groups and hyphenated societies, and certain influential newspapers which carry heavy steamship advertising. *All of these are bent on making any restriction whatever appear unreasonable, unjust and inhumane.* It is very important that the character, the motives and the tactics of this opposition should be known.

OUR GENERAL IMMIGRATION LAW MUST BE MAINTAINED AND ENFORCED

There can be no question that our general immigration law of 1917 must be maintained. This law names some thirty classes of

aliens who are excludable on mental, physical, moral or economic grounds. These include the insane, the idiot and the feeble-minded; those who have loathsome or dangerous contagious diseases; criminals; prostitutes; persons physically incapacitated from earning a living, illiterates, etc. In fact the enumeration of the undesirable classes is so complete that, if the law had been and were always rigidly enforced, our immigration "problem" would give us far less trouble than it does. Our law bars criminals, but our court and institution records show a large excess of foreign-born. Our law bars the insane, but our insane hospitals, especially in the northeastern States, are filled with aliens. Our law bars those suffering from loathsome and dangerous contagious diseases, and those suffering from physical disability that may affect ability to earn a living, but political "pull" often suffices to admit over the doctor's certificate, against the express provision for exclusion. Our law debars paupers; yet an insignificant number of aliens is debarred on these grounds, although the majority of those now arriving come without money, and are not productive laborers.

In a recent paper on the deportation system of several States, Dr. H. H. Laughlin, of the Eugenics Record Office, Cold Spring Harbor, N. Y., brought together some startling facts.

> A recent survey shows that in 1916 the several states expended on an average of 17.3 per cent. of their total governmental expenditures in maintaining custodial and charitable institutions. This percentage varied from 5.4 in Alabama to 30.5 in Massachusetts. A survey of 460 state institutions for the several types of the socially inadequate, with a total of 210,835 inmates, recently (1922) completed by the Committee on Immigration and Naturalization of the House of Representatives, found 21.14 per cent. of these fifth of a million inmates to be of foreign birth and 44.09 per cent. to be of foreign stock—that is, of foreign birth or who have at least one parent foreign born. Thus if, on the average, it costs the same in the institutions to maintain native-born and foreign-born inmates, then currently the several states are expending approximately 7.62 per cent. of their total revenues in caring for degenerate and dependent human foreign stock. This is the logical outgrowth of the asylum idea which has pervaded the American immigration policy.

The proper enforcement of our general immigration law involves not only a very careful and deliberate scrutiny of all arriving aliens, but also a systematic and thorough round-up of all aliens already in this country who are deportable because they have become public charges, or who have been found to belong to certain other specified classes of undesirables which are by law subject to deportation. Never yet since the law of 1917 has been on our statute books has it been strictly enforced. It is to the credit of the present administration that a distinct improvement in

this respect was made during the past year. And it should be remembered that strict enforcement leads to a certain extent to self-enforcement, for the more aliens are debarred as undesirable, the fewer such attempt to get in.

THE PERCENTAGE LIMITATION MUST BE MADE PERMANENT

The present 3 per cent. law is not perfect, but it has on the whole worked successfully, and has fully justified its enactment. It is reasonably generous in permitting the reuniting of families; in allowing unrestricted entry to tourists and other excepted classes, and it has kept our ports open to a fairly considerable inflow of newcomers, for it should be remembered that it permits an annual immigration of over 350,000. It has undoubtedly worked hardships in some cases, but most of the newspaper stories of such hardships have either been intentionally exaggerated, or have been untrue. Public sympathy is easily aroused by a single instance of real or fictitious hardship. The far more vital problem of how the present character of immigration is to affect the American race of the future is more remote, and attracts less attention. The administration of the law is fortunately in the hands of officials who are enforcing it with justice and humanity.

There is one point in connection with the 3 per cent. law which is often lost sight of. For a good many years before the war, aliens from southern and eastern Europe largely outnumbered those from northern and western Europe. Under the new law these numbers are nearly equalized, so that if all nationalities fill their allotted quotas, the so-called "newer" immigration can not contribute more than about one half of our annual inflow. This fact is biologically of great significance. In the fiscal year ending June 30, 1922, deducting emigrants from immigrants, we gained in Nordic stock, and lost in the natives of southern and eastern Europe.

Those who attribute solely to the present percentage restriction the need of labor in certain industries are either wholly ignorant of the facts, or are intentionally trying to mislead the public in the effort to break down all restrictions and to flood the country with cheap labor. In this connection it should be realized that (1) there has been a very considerable emigration of alien labor during the recent period of business depression and unemployment; (2) if all countries filled up their quotas, which they have not been doing during the past year, there would be an annual inflow of over 350,000; (3) the countries of northern Europe have fallen much farther below the quotas than those of southern and eastern Europe, most of the latter having exhausted their quotas, thus showing that the intelligent and skilled labor of northern Europe

has not been disposed to emigrate to the United States; (4) the immigration of aliens who are natives of any countries of the New World is not subject to the provisions of the law; (5) a considerable proportion of our immigration under the 3 per cent. law has been made up of sweat-shop workers, peddlers and small shop-keepers, not of strong, sturdy, intelligent laborers. This is clearly not the fault of the law, but results from the present tendencies of immigration. Thus the "need of labor" is by no means to be attributed solely, or even largely, to the percentage law. Furthermore, there is little doubt that northern and western Europe will fill up its quotas during the coming year, as immigration from those countries is increasing. The relation of immigration restriction to the rising scale of wages was so clearly stated by Honorable Albert Johnson during the closing days of the session of Congress recently ended that we can not do better than to quote from his remarks on this point.

> Every good American sympathizes with workingmen in their effort to obtain decent wages and decent conditions. . . . Restriction is an absolutely necessary supplement to a protective tariff. Immigration must be curtailed until all workers, native and foreign-born, whether in the basic or other industries, get wages and have conditions commensurate with American standards and ideals if we are to maintain those standards, ideals, and, in fact, our very civilization. Just as soon as wages in those industries rise to the point where the breadwinner can rear and support his family in keeping with American standards, the native-born will reinvade those industries from which they have been driven by the ruinous competition of imported cheap labor, often inducted into conditions amounting to slavery, and when wages do rise to that level the native supply will quite meet the demand, just as native labor does in every other country.

This is the situation in a nut-shell.

As a result of the awakening on the part of our people to the effects of the practically unrestricted new immigration from southern and eastern Europe and Asia, for the first time, and against bitter opposition, the principle of numerical limitation has been established by overwhelming majorities in Congress in a manner which gives equal treatment to all the nationalities which make up our population as far as is consistent with the maintenance of what we know as America. This principle, which has been long and strongly advocated by leading authorities on immigration, should be made our permanent immigration policy. Our own country, foreign countries, the steamship companies—all have become more or less adjusted to a definite numerical limitation of our alien immigrants. The machinery is in operation, and works remarkably smoothly, as much so as any restrictive legislation ever works. In reenacting a percentage law, whether it be the present 3 per cent., or the 2 per cent. which has been suggested in certain

bills lately introduced into Congress; and whether the percentage quotas be based on the census of 1910 or an earlier census, it would be wise to make the law somewhat more elastic. Reasonable provision should be made to prevent the breaking up of families. This could readily be accomplished by treating the *immediate* members of a family as a unit whenever some members could be admitted without exceeding the quota while the remaining ones would otherwise be excluded because exceeding the quota. Exceptions in favor of bona-fide tourists, of students and of professional classes are necessary. Further, a maximum number of 500 or 600 could wisely be set for the admissible aliens from certain countries whose quotas are very small under the 3 per cent. provision, and from which we receive highly desirable immigrants. The quota from Australia, for example, in the present fiscal year is only 279 and that from New Zealand and Pacific Islands is only 80. With these changes, a percentage law such as the present one would involve very few hardships. At the same time if the exceptions were carefully drawn, there would be no danger of our being swamped by any such flood of aliens as swept in upon us before the war, and as will, in even greater volume come in again unless we take steps to prevent it.

It can not be too strongly emphasized that, while the original argument in favor of the 3 per cent. law was economic, the real, fundamental, lasting reason for its continuance is biological. This side of the matter was so clearly and forcibly presented in an editorial note in the October number of the *World's Work* that we can not do better than to quote that statement here:

> If America is to realize its fullest possibilities, it must exercise the principle of selection. Up to the present time it has ignored this method. Our policy of opening our gates to all comers has really meant that we have recognized no distinctions among peoples, that we have refused to admit that one presented better material for citizenship than another, and that we have pinned our faith on the existence of some wonder-working alchemy in the American atmosphere which could transmute an inferior race into a superior one. But the teaching of all history, as well as the experiments of the biological laboratory, show the absurdity of any such easy-going philosophy, and the nation has reached the point where it should base its future upon scientific and historical fact.
>
> This is really the argument in favor of the three per cent. immigration law. It does not directly apply this principle of selection, it is true; that is, it does not in so many words limit immigration in future to particular races and particular nations. Yet indirectly it does accomplish a result which is not dissimilar. It takes the population of 1910 as representing the proportions of different peoples which, under the practical limitations of the problem, may be regarded as furnishing the desirable racial composition of the future United States. The great majority of that population came from the countries of northwestern Europe—Germany, Scandinavia, Great Britain and Ireland. There are few who have studied the matter who do not regard these

peoples as the most desirable elements with which to construct the nation. By limiting future arrivals to three per cent. of these stocks, therefore, the law does provide that the American people of the future, as well as of the present, shall be chiefly from the races of northwestern Europe. That is the reason why this law, or one based upon the same principles, should represent the permanent policy of the republic.

Objections to a Flat Numerical Limitation without Proper Selection

The sole purpose of such a numerical limitation as that embodied in the present 3 per cent. law is to cut down numbers. Because immigration was largely of an undesirable quality we cut it down. The 3 per cent. law certainly does let in a smaller amount of bad stock, but does not improve the stock, physically, mentally or morally. It doubtless shuts out some highly desirable immigrants because the quotas are mostly filled with undesirable ones. Furthermore, being based on nationality, *i. e.*, country of birth, and not on race, it has made possible a disproportionate immigration of Jews to the exclusion of thousands of non-Jewish aliens. This fact comes about because of the extraordinary activities of Jewish relief societies, both in this country and in Europe. These organizations take all the steps necessary to enable their co-religionists in Europe to emigrate to the United States, such as procuring their passports, purchasing their passage tickets, and caring for them *en route* to the ports of embarkation. Thus the annual quotas from several European countries are largely filled with Jews. In this way the "flat" percentage restriction has been worked with injustice to non-Jewish aliens who desire to come to the United States.

It is because a flat percentage restriction works only quantitatively and not qualitatively that it is absolutely necessary to maintain and to enforce our general immigration law of 1917, as urged above.

Overseas Inspection of Prospective Immigrants is not practicable

There seems to be so many and such obvious advantages, both to the prospective immigrant and to the United States, in having some sort of examination overseas, that there is at present a widespread demand for such inspection. This is no new agitation. It has marked the history of immigration literature and debate for at least thirty-five years. Such foreign inspection would seem to be our only way of looking into the antecedents, habits and character of our intending immigrants; of picking out those who by heredity and education are best fitted to become American citizens; of eliminating, at the source, all those who, under our general immi-

gration law, are physically, mentally, morally or economically undesirable. Overseas inspection suggests itself as a humane method of stopping most of the inadmissible aliens before they start on their voyage, and it should be welcomed by the steamship companies, for it would mean that few rejected aliens would have to be taken back at the companies' expense.

The plan recently most widely advocated is that the United States should establish an immigration office in each consulate to function in connection with the work of viséing passports, the immigration inspectors to certify as to an alien's admissibility to this country before his passport is viséd.

On its face this plan seems sensible, wise and humane. It seems to offer a simple and practical solution of the immigration problem. Yet there are so many objections to it, and so many obstacles in the way of its accomplishment, that for years all committees of Congress which have considered it, as well as the Immigration Commission of a decade or so ago, and leading authorities on immigration, have been forced to abandon it. A first objection to overseas inspection is that it would necessitate a very large increase in the number of immigration inspectors and medical officers, with the resulting heavy expense. If an undesirable alien is to be stopped before he leaves home and if the antecedents and character of our prospective immigrants are to be accurately ascertained, we must have our inspectors and doctors at all the thousands of places all over Europe and western Asia from which our immigrants come. For it is obvious that a United States immigration inspector at a consulate in Hamburg, *e. g.*, making an examination there of, say, a thousand Jews coming from all parts of Poland, would be no better able to determine their eligibility there than on their arrival at Ellis Island. Of course, those who might be declared inadmissible by the inspector at a European port, or at some inland city where we have a consulate, would be saved the voyage across the Atlantic, but complete information concerning any alien could only be obtained in his home town or hamlet. In the second place, overseas inspection would divide the responsibility between the officials abroad and those at our own ports, for there is no question that we must, under any and all conditions, always maintain our inspection service at our ports. In all doubtful cases, each inspector, the one abroad and the one here, would throw the responsibility upon the other. Thirdly, overseas inspection, supplemented by home inspection, would work hardship on the aliens because it would never be certain that all with overseas certificates would be allowed to land on a second examination here.

Lastly, whenever overseas inspection of prospective immigrants has been seriously considered by Congress, certain foreign govern-

ments have objected to it on the ground that this country would thereby be assuming extra-territorial sovereignty not in accordance with treaty rights. Delicate diplomatic problems are here involved. No scheme for foreign inspection could be devised which did not use the existing machinery of consular offices. As the Honorable Albert Johnson has recently said, "Our consular offices are established under authority of trade and commercial treaties, each of which sets forth specifically what functions may be carried on by consular employees. Examination of persons who contemplate migration to the United States is not included. It follows that if we are to set up a plan for examination of immigrants overseas we must of necessity revise many of our trade and commercial treaties." This is the situation in which the United States finds itself in this matter of overseas inspection.

It is obvious that the interests of the United States and those of foreign countries are absolutely opposed in this matter of immigration selection. We want the sound, able-bodied, intelligent. We do not want the defective, the delinquent, the physically unfit. The former are the ones most desired at home. The latter, foreign governments would not regret to have emigrate. It is, therefore, readily understood why these governments may not be too ready to acquiesce in any new arrangement whereby we can select the best and refuse the worst of their people. The present passport and visé system gives foreign governments the power to designate and to allow to emigrate those persons only whose presence in their own countries is not desired. The selection of our future citizens is therefore not in our own hands.

In spite of the present obstacles in the way of our establishing overseas inspection, it might perhaps be possible, through ordinary diplomatic channels, without the necessity and the delays of negotiating any new treaties, to come to an amicable working agreement—a Gentlemen's Agreement, in short—with the governments of foreign countries from which our immigrants come, whereby, by international cooperation, the United States could make some sort of a preliminary examination of intending immigrants before they sail. If the present administration could bring about such an agreement, it would take a long step in the settlement of this most difficult and important national problem. The sympathetic attitude of the present Secretary of Labor on this question has been clearly indicated. Thus, in an address given in Boston on June 14 last, he said (*The Boston Herald*, June 15) "We must bar out those who menace our national life and our national institutions. Much could be done by providing for inspection of prospective immigrants in Europe before they undertake the long journey

across the Atlantic. I would insist upon the most rigid tests of blood, physical, mental and moral stamina before admitting a single immigrant." With this view all patriotic and thinking Americans must surely agree.

Overseas inspection, however, desirable as it would be, should not and could not in any way replace the other restrictive and selective measures advocated in the foregoing discussion. We imperatively need a stricter enforcement of our general immigration law, and a permanent percentage limitation with the amendments above suggested.

ADDENDUM: If we want the American race to continue to be predominantly Anglo-Saxon-Germanic, of the same stock as that which originally settled the United States, wrote our Constitution, and established our democratic institutions; if we want our future immigration to be chiefly made up of kindred peoples from northern and western Europe, easily assimilable, literate, of a high grade of intelligence, able to understand, appreciate and intelligently support our form of government, then the simplest way to accomplish this purpose is to base the percentage limitation upon an earlier census than that of 1910, *i. e.*, before southern and eastern Europe had become the controlling element in our immigration. In an important discussion of "The Immigration Problem," in *Scribner's Magazine* for September, 1922, which came to the present writer's attention after he had completed the foregoing article, Professor Roy L. Garis, of Vanderbilt University, suggested that our permanent legislation be based upon the percentage principle, but that we admit 3 per cent. of the different nationalities of foreign-born in the United States as shown by the census of 1890. This, as Dr. Garis rightly says, "is a simple yet practical solution, based on historical facts." If instead of 3 per cent. we should admit 5 per cent. of the foreign-born resident here in 1890, the annual total for all Europe would be 400,000, in round numbers. Of these, about 200,000 would be admissible from northwestern Europe; 50,000 from Scandinavian Europe; 165,000 from Central Europe; 10,000 from eastern Europe; 10,000 from southwestern Europe, and 2,000 from southeastern Europe. Such a law would result in bringing in a large preponderance of immigrants who present no difficulties of assimilation; who do not give rise to our immigration "problem." It would thus be automatically selective, as well as numerically restrictive. If we are to maintain the physical and mental standards of our race; if we are to make America safe for democracy, to keep America for Americans, there is no more logical or practical method than this.

A MODERN MECCA

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THE ancient Arabian city of Mecca is in one sense the most remarkable in the world. It is the birthplace of Mahomed, the *Resoul 'Illah*, or prophet of God, and it contains the Kaaba, or central shrine of the Mahomedan faith. No giaour may enter there. Very few Christians have ever seen the place. The explorer Burton, for instance, one of the most famous oriental linguists, penetrated there, under elaborate disguise, at the risk of his life.

Over two hundred millions of persons—about one eighth of the population of the globe, or nearly double the population of the United States—are reputed Mahomedans. The great majority of these Mahomedans are devout worshippers, according to the ritual of the *Koran*. Several times a day, notably at dawn and sunset, the faithful, scattered over Asiatic and African lands, unfold their prayer-carpets, lay them in the assumed direction of Mecca, and prostrate themselves thereon in prayer. This custom of diurnal obsequience towards the prophet's holy city has continued for centuries with very little change. Mecca has thus maintained a marvellous hold upon the daily thoughts and acts of a vast number of human beings. In their psychology, the Kaaba is the common and universal point of reference. Their lives are lived in perpetual procession towards that one place. Every year, about one hundred thousand pilgrims of zeal journey from afar to visit it. He who has thus attained to the holy city acquires with pride the title of *Hajji*, which entitles the owner to social respect.

Although the modern world has created no new Mecca in any such sense as Mahomedanism conveys, yet in a certain very remarkable way it has created a scientific Mecca at Sèvres, in the beautiful park of St. Cloud, on the Seine, near Paris, and close to the famous old Sèvres porcelain factory. Here, on a plot of land which France has given to the world, by extraditing it from French boundaries, is an unpretentious building, called the "*Bureau International des Poids et Mesures,*" especially constructed in 1875, for enabling accurate measurements of standard lengths and weights to be carried on quietly, and at a nearly uniform temperature, within its walls. Eight meters beneath the surface of its courtyard is a vault containing a closed steel safe, wherein are treasured the

world's most valued reference standards of length and weight—the international meter and kilogram—together with certain "*témoins*" or ancillary duplicates. The building is mainly devoted to comparisons between these fundamental standards and the corresponding replica of other nations, through the medium of working copies. It has no upper stories and is surrounded by the forest park. Fortunately for the even tenor of its duties, it ordinarily escapes attention from the ubiquitous tourist, despite its proximity to the much visited porcelain museum. Neither Baedeker nor "Guide Bleu" refers to it, and it finds no place on the list of objects to attract the interest of the visitor; yet it may properly be described as a latter-day temple for the guardianship of the "Lares and Penates" in the world of weights and measures. The expense of its upkeep is shared, in definitely prescribed proportions, among the twenty-eight foremost countries of the world.

The need for an international clearing house and depositary for the world's standard meter becomes evident from a consideration of industrial needs alone, as well as from a cursory glance at the history of the subject.

If a steel bar, say one yard in length, is ordered, without any further specifications, from a smithy, we might reasonably expect the bar to be delivered true to length within one per cent., more or less; that is to a precision of one part in 100, or 10^2. This may be described as a precision of the second order. It does not mean that the smithy could not furnish a higher degree of precision in length, if the need existed; but merely that in the ordinary course of business, a yard bar at the smithy might well be interpreted to include bars longer or shorter than a yard by as much as one per cent. Moreover, the measurement of the bar, by the act of laying a yard-stick alongside it, would be an operation lasting only a few moments. Nevertheless, if the tolerance of something more than one per cent. were clearly admitted, the moral certainty of the measure within those limits would be very great. Any intelligent man receiving the bar from the smithy, and laying a creditable yard-stick beside it, could see at a glance that the two were nearly alike in length; so that unless some question as to the amount of tolerance were raised, he would feel a high degree of assurance that—in the common use of language—the bar was a yard long.

The rough bar from the smithy might next be sent to a machine shop with an order that it be trimmed, smoothed and cut to a finished length of say 35 inches; but without any specifications as to tolerance in precise length. In the operations of smoothing and finishing, the mechanic entrusted with the order, would probably

spend a little time in adjusting its length to "35 inches." One per cent. he would regard as unworkmanlike, and he would probably aim at a precision say of one per mil; *i. e.*, one part in 10^3, or of the third order. If he were put upon his mettle, he might be willing to attempt a precision of the fourth order, or 1 in 10^4; but the extra time involved in such an effort might not be justifiable. Even to reach the third order, he would have to make the length correct within 0.035 inch, and much more time would be needed in the measurement than was spent at the smithy in attaining the second order. In the first place, an ordinary rough yardstick would no longer suffice. A graduated steel tape or straight edge would be necessary. Moreover, the operation of juxtaposition and reading off the length would take much longer than before. Finally, in spite of this increased mental and physical care in the task of measurement, the degree of moral certitude as to the reliability of the result will probably not have increased proportionately. In repeating the measurement, the mechanic will begin to arrive at slightly different results and the effect of the discrepancies disconcerts the judgment. Of course, unless the mechanic made a gross error or mistake in reading the tape, he would feel convinced that the finished bar was much nearer to "35 inches" than one per cent.; but upon the new plane of third-order precision engaging his attention, he might feel less assurance of success than his predecessor, who measured only to the second order of precision at the smithy.

If now the finished 35-inch bar were sent to a superior workshop, to be assembled perhaps in some fine piece of mechanism, after being adjusted to say 34.8 inches, at a room temperature of 20° Centigrade, with a tolerance of 0.004 inch, this would entail refinishing the ends of the bar and measuring its new length to one part in 10^4, or to fourth order precision. For the purpose of making this measurement, a special gauge might have to be prepared. If the bar in the assembled mechanism had to be made interchangeable with similar bars coming from other machine shops, the gauge might have to be adjusted to a precision of the fifth order in length, at a special workshop for the construction of precise gauges. In order to reach fifth order precision in the gauge at the special workshop, a standard measuring rule of yet higher precision would be needed there. It would not be unreasonable to require a precision of the 5½th order in that special workshop standard. That standard would probably be compared and calibrated against a still finer standard at the Bureau of Standards in Washington, where a precision of the 6.5th order, or one per 3,000,000 might be readily obtainable. Finally, to keep the stand-

ards of the different national laboratories of the world in mutual agreement, an international standard is maintained at Sèvres, where the precision attainable is of the seventh order.

It is clear that every measure of length, either in the world of business or in the world of science, has its order of precision, over the entire range from the first to the seventh, depending upon its construction and purpose. No one expects a higher order of precision than the particular purpose of the measure in question demands; because the effort and expense involved in securing an extra order of precision is relatively great. There are certain lines of industry, notably in gauge making for fine tools, where fifth order precision is necessary. Not many decades ago, this was the highest order scientifically attainable in measures of length. The advance from the fifth to sixth order demanded an immense amount of scientific and industrial effort. Progress had to be made in the mathematics of accidental errors, in metallurgical chemistry to provide improved materials, in physics to learn the laws of length variation in material standards, in tools, to fashion the improved parts, in workmanship and experience to handle the new tools. At the present date, we can look for the seventh order precision in the comparison of the various national meters with the international meter at Sèvres; but although this suffices for practically all industrial needs, it is inadequate for certain scientific requirements. Certain problems of the Einstein theory, for instance, might find solution, if the eighth or ninth order of precision in the measurement of length were attainable.

If material civilization advances, we may hope to secure one higher order of length precision at Sèvres in the course of another century. This would probably add one order to national scientific length measurement all over the globe. Apart from questions of moral or spiritual development, an estimate of the world's civilization might be furnished, based upon the order of precision realizable in the certificates of meter-bar comparisons furnished by the bureau at Sèvres.

The permanence and inviolability of the international meter are clearly of importance to all nations. The control of the Sèvres bureau has been vested, since 1875, in an international body composed of delegates from the twenty-eight leading national governments that are parties to the bureau's maintenance. The international meter and kilogram are deposited at the bureau in such a manner that seven successive keys have to be used in order to reach them. Three of these keys are in regular service for the doors of the building; but the four others belong to the special vault in which the standards are preserved, and are placed in the

custody of as many different officers of the international committee. Some of these officers live abroad; so that the keys are usually kept far apart. It has thus only been possible to open the vault at the regular six-year meetings, when the assembling officers produce their respective keys. The inconvenience of so inflexible a *modus operandi* manifested itself during the world war. At the outbreak of the war, one of the officers, entrusted with a key, resided in Germany. That key, being in an enemy country, was inaccessible. If Sèvres had been subjected to bombardment, it would have been necessary to remove the standard meter and kilogram to a place of safety, and this would have involved breaking into the vault. In order to provide against such a contingency in future, a new set of regulations has been brought into effect; whereby a duplicate of each vault key is deposited with the Institut de France, and so that, under special emergency, the vault can be opened by its authority.

One of these six-year meetings of the International Conference took place recently in Paris under the presidence of M. Emile Picard, the permanent secretary of the French Academy of Sciences. On October 6th, 1921, the delegates met at Sèvres and at a specified hour formed themselves into a visiting and attesting committee, under the leadership of M. Ch. Ed. Guillaume, the Director of the Bureau.

The committee members line up across the courtyard in column by twos. At the signal, the procession enters the main and east door of the Bureau, and passes along a corridor, in the half light, to a descending stone stairway. Incandescent lamps light up, and we descend to a basement floor. Again, down another stone stairway, to a sub-basement. At this level, the temperature changes but little all the year round. We now face the first of the three steel vault doors in the east wall. It opens to the corresponding official key. Behind it are two other steel doors, which are successively unlocked, revealing the vault beyond. This is about 4 meters long in an easterly direction, 3 meters wide and three high. An electric incandescent lamp, that has been idle for eight years, is turned on and we can see the interior clearly. The walls and ceiling are lined with white enamelled brick. Opposite to the entrance against the eastern wall is a table supporting a steel safe. There is nothing else in the vault except an auxiliary table against the north wall. The director produces the last of the seven keys and unlocks the safe. Its doors swing open and disclose two shelves. On the upper shelf are three meter-bar cases, a minimum-maximum thermometer and a hygrometer. On the lower shelf is a row of five glass double bell-jars. Inside of each is a shin-

ing cylindrical standard kilogram. The director calls for a reading of the instruments, which have been shut up in the safe since 1913. The min-max, thermometer register 10.6°—13.2° Centigrade, or a total range of only 2.6 degrees during those eight years. The hygrometer shows 88 per cent. humidity. The director calls attention to the international meter and kilogram, with their control duplicates. He carefully lifts out of the safe the central case, containing the primary standard or prototype meter, and lays it on the auxiliary table. He opens the case and reveals the brightly gleaming meter bar within. Like all the other standard bars, its section is of a special X shape, so designed as to offer the maximum stiffness, or resistance to sagging in the middle, when the bar is supported at its two ends. Of course, a stout platinum-iridium bar, a little more than forty inches long, and built with any reasonable shape of cross-section, would sag very little at the center when the bar is supported at its ends. Nevertheless an extremely small sag would be apt to alter, in perceptible degree, the apparent length of the bar, as measured on its surface. By giving this X shape to the section, and cutting a flat strip of surface at the middle of the groove in the X, the meter length is marked off along this flat strip, where the change in length due to any possible central sag becomes quite negligible. The meter bar is not graduated, or marked off into equal divisions like an ordinary rule. There is merely a fine scratch cut with a diamond point across the bar near each end. The international meter is defined as the distance between these two fine line scratches, when the bar is at the temperature of melting ice.

No hand touches the bar, which lies face down in its case. It is the final reference standard, and does not need to be used except as a final arbiter, in case differences should arise among the working standards. Its duty is merely to remain steadfast—to preserve its dimensions unchanged.

Only a few of the witnesses can occupy the vault at one time, and the air in it becomes oppressive. As soon as those within have recognized the contents of the safe, they leave the vault and make room for others.

In about half an hour, the standards are replaced on their shelves, the safe is shut and locked, the light is turned off and the vault doors closed. The world's standards of length and weight thus resume their wonted repose, until the next awakening by a visiting committee, probably six years hence. This visiting committee, however, returns to daylight and reforms in the courtyard, where it is photographed by a moving-picture machine, to record the passage of its members.

The measurement laboratories of the Bureau are also visited by the committee. These laboratories have specially constructed walls, to keep the temperature within them nearly uniform. In one of them, standard meter bars are compared and certified. The bar to be tested is laid horizontally on end supports in a tray of water, alongside of the working standard of the laboratory, whose error with respect to the international meter of the vault has been carefully determined. Being composed of platinum-iridium, the bars do not tarnish under water; although they have to be cleansed from deposits of dust or organic matter—of which more anon. The immersion of the bars in water is desirable during the tests, in order to enable their temperature to be more closely determined, each bar being only true to length at a certain temperature, and correction being necessary for observed deviation of temperature from the standard.

A microscope is supported on a stone pillar over each end of the bar, in such a manner that the cross-hair of the eyepiece can be brought over the delicate line marks on the ends of each bar in turn, the operations being regularly repeated many times according to a definite schedule. The observations, as finally collected and reduced, reveal the difference between the length of the tested bar and that of the working standard. Readings can be taken to the eighth order, or to 0.01 micron (10^{-8} meter, about 1/2,500,000th inch; but the final result is only depended upon to the nearest 0.1 micron, or ten-millionth of a meter, a precision of the seventh order. The micron is the one-millionth of a meter, and is the unit of length in practically universal use among scientific workers with the microscope, all the world over.

Some excitement was recently aroused at the Bureau, by the discovery that two working standard meter bars, in use there during many years, although retaining their lengths almost unchanged with respect to each other, had both lengthened in that time by about 0.4 micron, or 1/65,000th of an inch, the change of length being progressive. After much search, it is believed that this minute lengthening of each bar has been gradually brought about through the constantly repeated cleansing of the polished working surface by the gentle rubbing of a cloth. The rubbing had always been directed, as a matter of habit, along the bar towards the end. In this way, it is supposed that the walls of the fine diamond scratch across the bar, near each end, were slowly pushed over and away from the middle of the bar, by 0.2 micron, in the course of long usage. It has since become the prescribed routine to clean the surface of a meter bar by rubs delivered alternately in opposite directions.

Another laboratory is devoted to the measurement of standard weights. In each corner of this room a delicate balance weighing machine is mounted, while the observer sits in the middle of the room at a distance of four meters from each and all of them. The reason for his having to sit so far from his work is that if he were to take up a position comfortably close to the balance he operated, the warmth from his body would probably vitiate the measurements seriously for the degree of precision aimed at, in spite of the usual windows and shields with which such a balance is ordinarily provided. His respectful distance from the subject of his investigation suggests the old rhyme:

"Who suppes with ye Deville
Shoulde have a longe spoone."

With the aid of an ingenious arrangement of four parallel and horizontal brass rods, running from the balance to the observer, and which he can rotate in different ways, he is able to weigh the test kilogram mass against the mass of a standard kilogram, on the scales four meters off, and to read the balance through a telescope. One of these four-rod combinations enables him to observe the difference of weight between say the tested mass on the left-hand scale, and the standard mass on the right-hand scale; then to clamp the beam, next to lift off the two weights and reverse their relative positions, bringing the tested mass to the right and the standard mass to the left; and finally to repeat the weighing in this reversed relation, all at four meters' distance.

A standard kilogram is a solid cylinder of polished platinum-iridium, with its circular edges slightly rounded. The mass of such a cylinder can be measured, after making all corrections, to the nearest hundredth of a milligram; or to the 10^{-8} kilogram—a precision of the eighth order. It is curious that the available precision of mass determination should thus be one order greater than that available in length determination in our national standards, at this period of the world's history.

It is evident that a blow, or severe mechanical shock, administered to any standard meter bar, might readily alter its length and render its use unreliable. Great care has to be taken in the national laboratories of the various countries not to let a standard meter bar fall. Occasionally, a national standard meter bar is brought back to Sèvres from some distant part of the world for recomparison at the Bureau. In such a case, it is always entrusted to a careful messenger, and usually the chief of the national laboratory takes it himself. At last October's Paris meeting two national meter bars came back for retesting, one from Washington, D. C., and the other from Japan. In each case, the director of the

The measurement laboratories of the Bureau are also visited by the committee. These laboratories have specially constructed walls, to keep the temperature within them nearly uniform. In one of them, standard meter bars are compared and certified. The bar to be tested is laid horizontally on end supports in a tray of water, alongside of the working standard of the laboratory, whose error with respect to the international meter of the vault has been carefully determined. Being composed of platinum-iridium, the bars do not tarnish under water; although they have to be cleansed from deposits of dust or organic matter—of which more anon. The immersion of the bars in water is desirable during the tests, in order to enable their temperature to be more closely determined, each bar being only true to length at a certain temperature, and correction being necessary for observed deviation of temperature from the standard.

A microscope is supported on a stone pillar over each end of the bar, in such a manner that the cross-hair of the eyepiece can be brought over the delicate line marks on the ends of each bar in turn, the operations being regularly repeated many times according to a definite schedule. The observations, as finally collected and reduced, reveal the difference between the length of the tested bar and that of the working standard. Readings can be taken to the eighth order, or to 0.01 micron (10^{-8} meter, about 1/2,500,000th inch; but the final result is only depended upon to the nearest 0.1 micron, or ten-millionth of a meter, a precision of the seventh order. The micron is the one-millionth of a meter, and is the unit of length in practically universal use among scientific workers with the microscope, all the world over.

Some excitement was recently aroused at the Bureau, by the discovery that two working standard meter bars, in use there during many years, although retaining their lengths almost unchanged with respect to each other, had both lengthened in that time by about 0.4 micron, or 1/65,000th of an inch, the change of length being progressive. After much search, it is believed that this minute lengthening of each bar has been gradually brought about through the constantly repeated cleansing of the polished working surface by the gentle rubbing of a cloth. The rubbing had always been directed, as a matter of habit, along the bar towards the end. In this way, it is supposed that the walls of the fine diamond scratch across the bar, near each end, were slowly pushed over and away from the middle of the bar, by 0.2 micron, in the course of long usage. It has since become the prescribed routine to clean the surface of a meter bar by rubs delivered alternately in opposite directions.

Another laboratory is devoted to the measurement of standard weights. In each corner of this room a delicate balance weighing machine is mounted, while the observer sits in the middle of the room at a distance of four meters from each and all of them. The reason for his having to sit so far from his work is that if he were to take up a position comfortably close to the balance he operated, the warmth from his body would probably vitiate the measurements seriously for the degree of precision aimed at, in spite of the usual windows and shields with which such a balance is ordinarily provided. His respectful distance from the subject of his investigation suggests the old rhyme:

"Who suppes with ye Deville
Shoulde have a longe spoone."

With the aid of an ingenious arrangement of four parallel and horizontal brass rods, running from the balance to the observer, and which he can rotate in different ways, he is able to weigh the test kilogram mass against the mass of a standard kilogram, on the scales four meters off, and to read the balance through a telescope. One of these four-rod combinations enables him to observe the difference of weight between say the tested mass on the left-hand scale, and the standard mass on the right-hand scale; then to clamp the beam, next to lift off the two weights and reverse their relative positions, bringing the tested mass to the right and the standard mass to the left; and finally to repeat the weighing in this reversed relation, all at four meters' distance.

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national laboratory brought it in person. In the American instance, Dr. Stratton brought the meter bar from the Bureau of Standards at Washington, with the aid of an assistant. The special case containing this meter always remained in the care of one or the other, being carried from place to place with more care than a mother ordinarily devotes to the handling of her baby. A tumble that might not hurt a baby might injure a meter bar. In the Japanese instance, Dr. Tanakadate arrived at Sèvres, after a journey from half way round the world, carrying his meter case in his arms. The way in which the precious national standard was carried in each instance brings to mind the story of the Italian knight, the founder of the well-known Pazzi family, who, in one of the crusades, returning from Jerusalem on horseback, always sat backwards, or facing the tail of his horse, because he tended constantly a little fire in a brazier, whose embers he had first lighted from the sacred fire in Jerusalem. Journeying painfully and slowly, he was determined to bring the fire still alive to his native Italian city. His unusual gait and attitude naturally aroused much astonishment on the journey, and the name "pazzo," or crazy, clung, so the story goes, to him and his family thereafter.

The reason for so much care being warranted, moreover, in the American instance was that both by act of Congress and by executive order, the U. S. Yard is defined and maintained as a certain definite fraction of the international meter, as is also the U. S. pound avoirdupois as another definite fraction of the international kilogram. Consequently, all American measures are linked with the fundamental units at Sèvres. Although the Washington Bureau of Standards has more than one official copy of the meter; yet it is advantageous to have one of the copies checked and recompared at "Mecca" from time to time.

After the international bureau at Sèvres was organized in 1875, and set to work making and certifying copies of the international meter and kilogram, 30 standard meter bars in platinum-iridium were finished and approved by 1889. The bar which agreed most closely with the pre-existing standard meter of the "Archives" was adopted as the "international meter" for deposit in the vault, and the others were distributed by lot among the various contributing governments. Meter-bars Nos. 21 and 27 fell to the share of America, as well as Kilograms Nos. 4 and 20. The work of measuring and intercomparing the 30 standard bars, previous to their acceptance and distribution by the international committee, took over three years to accomplish.

Meter No. 27 and kilogram No. 20 were brought to Washington, under seal, by an officer of the U. S. Coast and Geodetic Survey.

and delivered to President Harrison at the White House on January 2nd, 1890. President Harrison, after breaking the seals and opening the cases himself, signed for their receipt and certified to the reception in good order of these national standards. These exercises were conducted with befitting ceremony, a special reception, followed by a social function and dance, being arranged at the White House for the occasion.

As originally planned, the meter was decimally derived from the dimensions of our universal mother earth, so as to be the ten-millionth of the distance from the North Pole to the Equator, on a meridian carried through Paris. In this way, if the meter should become lost or entangled in dispute, it might be re-established by geodesy. It would not, of course, be necessary to start with a tape-line from the north pole. It would fortunately suffice to measure the length of a portion or portions of an arc of the meridian, between terrestrial stations whose difference in latitude should be determined with the requisite degree of precision by astronomical methods. A series of meridian measurements were actually conducted about the year 1799, for the purpose of arriving at the length of the standard meter, although the best scientific instruments available at that date were distinctly inferior to those now in regular use. A marked advantage of this decimalized meridian basis for the meter is that with decimalized angles, which are slowly but surely winning their way to favor through ease in their calculation, the kilometer, or ten-thousandth of the earth quadrant, becomes the nautical as well as the terrestrial mile, thus bringing both land and sea under the dominion of the same standards. Recent measurements have shown that the actual standard meter is a little short of the theoretical meridian meter. With respect to the meridian through Paris, the standard meter is stated to be approximately 0.2 millimeter, or 200 microns, too short. This error is insignificant and negligible from the standpoint of sailor's charts, or navigational requirements; but it is an enormous error from the standpoint of national standard intercomparison at Sèvres. By the time that the shortcomings of the standard meter with respect to the theoretical meter became known, it was too late to change the standard. Moreover, supposing that the standard meter of to-day were corrected to the best known value of the theoretical meter; there can be no doubt that in the course of another century of progress in geodesy, the meter-bar thus corrected would have to undergo a new correction at that date, probably much less than the 200 microns now known; but yet very large with respect to inter-comparison work. The result would be that we should never have a final meter, and we should always

have to examine into the date of a meter-bar in order to be able to use it with a high degree of precision. For practical purposes, therefore, the world has been compelled to accept a standard meter whose precision with respect to the theoretically decimalized meridian is only of the 3.5th order, in order to secure a precision of the 7th order in replication and dissemination. In any case, the probable precision of redetermination by astronomical measures is at present much less than that attainable by direct meter-bar comparison. Consequently, if the standard meter should be lost in any one part of the world, it could always be re-established by reference to the international meter at Sèvres.

Will it always be necessary to make periodical comparisons between national meter-bars and the international standards at Sèvres? Perhaps not. Already a method has been developed, which, with the aid of the Michelson interferometer, enables the number of waves of cadmium red light to be counted in the length of one meter. This number has been stated to be 1,553,164.1, optically measurable with a precision of the seventh order, or practically the same as that of direct mechanical comparison. It may, therefore, be found, after sufficient experience has been acquired, that instead of sending a standard bar from Washington to Sèvres for calibration and certificate, it may only be necessary to use, in the Washington laboratory, the right kind of cadmium light, and to count off the right number of its wave lengths—a number exceeding a million and a half—in order to arrive at the length of one international meter, to the requisite degree of precision. Moreover, it is possible that yet another method may be found for deriving the meter locally, without making a pilgrimage to "Mecca" for it. At present, however, it is necessary to make the pilgrimage.

If then, we examine to-day any scale, divided rule, or measure of length, we always, either consciously or unconsciously, look towards Sèvres. The rule has always been marked off and graduated by comparison with a standard, and usually this standard has been more precise than the copy. If the graduated rule is very rough and imperfect, with a correspondingly low order of precision, we do not have to go far to find a possible standard of reproduction for it; but the finer and more nearly accurate the rule, the higher up in the scale of development we must search for a possible progenitor. The very finest in any country are only obtainable by direct comparison with the national standards. These, in turn, have been derived from Sèvres. Thus there is always a lineal succession of standards of length and of mass to every local inch, foot-rule or pound standard that is worthy of the name.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

BY DR. EDWIN E. SLOSSON
Science Service

REWARDS FOR WORKING INSIDE THE ATOM

Two Englishmen, one Dane and one German, are the winners of Nobel prizes in physics and chemistry for 1921 and 1922. The names just announced from Stockholm are Albert Einstein, of Berlin; Neils Bohr, of Copenhagen; Frederick Soddy, of Oxford, and Francis William Aston, of Cambridge. This is a striking illustration of the unity of science in spite of national divisions, for these four scientists have been in unconsidered cooperation trying to solve the same question, the most fundamental problem of the universe, what is the atom made of.

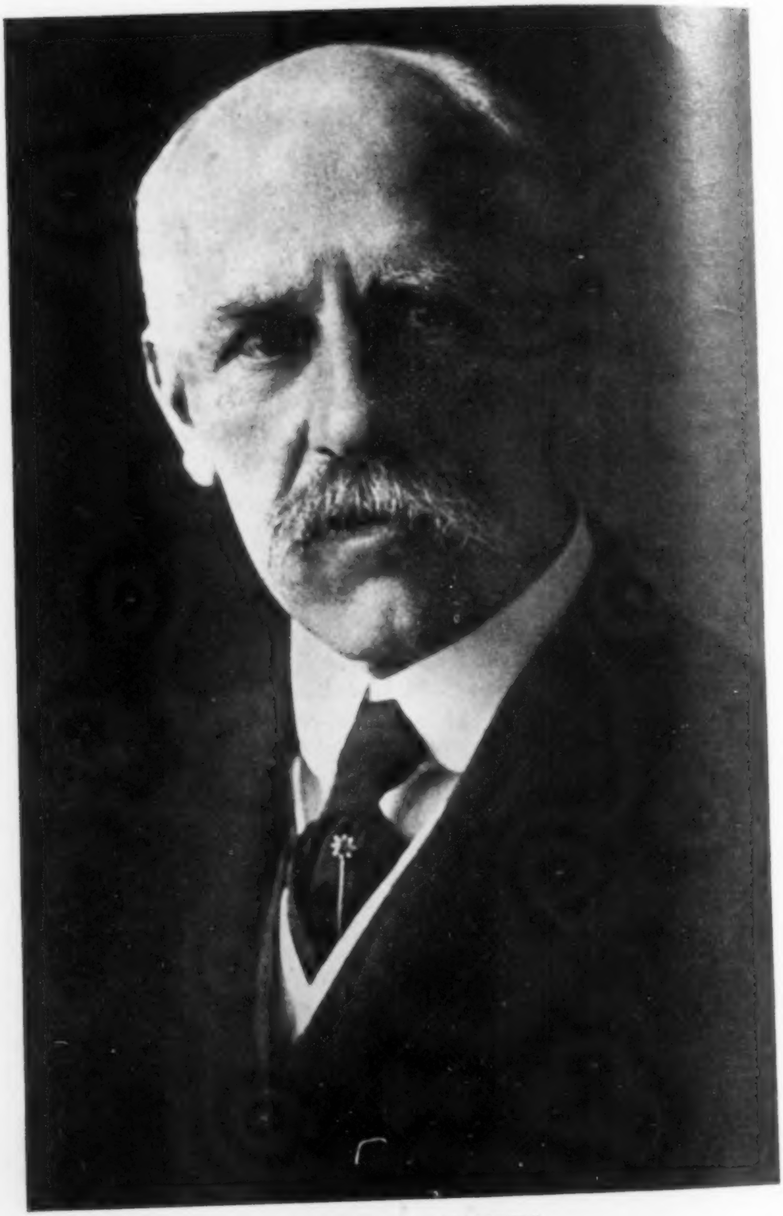
The atom was originally supposed to be the smallest thing possible, the ultimate unit of the universe. The ancient Greeks, who were the first to think about the question, concluded that if you kept on cutting up matter into smaller and smaller pieces you must come at length to something too small to be further sub-divided, so they called this smallest of all possible particles the "atom" which means "uncutable." The modern chemist took over this old Greek idea to serve for the combining weights of the elements and likewise assumed that the atom was the limit.

But early in the present century, Professor J. J. Thomson, of Cambridge, found radioactive matter giving off particles more than a thousand times smaller than the smallest atom, and for this discovery he received the Nobel prize of 1905. This opened up a new field of research that has been diligently prosecuted ever since, especially by British scientists. Professor Soddy has not only done a large part of this work but he has given a good popular account of what it means in his book, "Science and Life."

Chemists used to suppose that all the atoms of the same element were exactly alike in weight and every other way, wherever it came from, but this fixed idea has been upset. Soddy found, for instance, that lead from thorium ores is eleven per cent. heavier in its atomic weight than lead from uranium ores. Soddy named these different forms "isotopes." What are listed in chemical textbooks as atomic weights and were supposed to be unvarying turn out to be in many cases averages of several isotopes. Mercury, for instance, which is listed as having an atomic weight of 200.5 consists of six isotopes with weights varying from 197 to 204.

Aston devised an ingenious way of making the atoms record their own atomic weights. He drives a stream of positively charged particles between the poles of a powerful magnet which deflects them in the degree of their relative weights. When the dividing streams strike a photographic plate they leave their tracks and from these the mass of the various isotopes can be determined. Chlorine has always been a puzzle to chemists because its atomic weight figured 35.46 instead of a whole number. But subjected to the scrutiny of Aston's apparatus it is found to be a mixture of two kinds of chlorine atoms, one weighing exactly 35 and the other exactly 37.

The Scandinavian scientist, Bohr, was the first to venture on a picture of the new fashioned atom. We had



DR. FRIDJOF NANSEN

The distinguished Norwegian Arctic explorer and man of science, who has recently been occupying himself with the relief of sufferers from the Russian famine and is now engaged in similar work in Asia Minor.

been accustomed to think of atoms as round hard balls, but according to Bohr they are more like miniature solar systems with a positive electrical nucleus in the center and one or more negative electrical particles, called "electrons," revolving around it at tremendous speed.

Here is where Einstein comes in, for, while the planets moving majestically in their orbits obey Newton's law of gravitation, the electrons, which travel almost as fast as light, deviate from Newton's law in proportion to their speed and follow the formula of Einstein instead. According to Newton the mass of a body remains the same whatever its motion. According to Einstein, the mass increases with its velocity. The difference between them is inconsiderable for any ordinary speed, but when we are dealing with electrons moving at the rate of 100,000 miles a second it becomes important. The public has associated Einstein exclusively with astronomy because his theory has been tested at a time of eclipse, but the theory of relativity has applications quite as revolutionary and much more practical in earthly chemistry and physics.

HOW THE CHEMIST MOVES THE WORLD

The chemist provides the motive power of the world, the world of man, not the inanimate globe. Archimedes said he could move the world if he had a long enough lever. The chemist moves the world with molecules. The chemical reactions of the consumption of food and fuel furnish the energy for our muscles and machines. If the chemist can only get control of the electron, he will be in command of unlimited energy. For in this universe of ours power seems to be in inverse ratio to size and the minutest things are mightiest.

When we handle particles smaller than the atom we can get behind th elements and may effect more marvelous transformations than ever. The smaller the building blocks the greater the variety of buildings that can be constructed. The chemistry of the past was a kind of cooking. The chemistry of the future will be more like astronomy; but it will be a new and more useful sort of astronomy, such as an astronomer might employ if he had the power to rearrange the solar system by annexing a new planet from some other system or expediting the condensation of a nebula a thousand times.

The chemist is not merely a manipulator of molecules; he is a manager of mankind. His discoveries and inventions, his economies and creations, often transform the conditions of ordinary life, alter the relations of national power, and shift the currents of thought, but these revolutions are effected so quietly that the chemist does not get the credit for what he accomplishes, and indeed does not usually realize the extent of his sociological influence.

For instance, a great change that has come over the world in recent years and has made conditions so unlike those existing in any previous period that historical precedents have no application to the present problems, is the rapid intercommunication of intelligence. Anything that anybody wants to say can be communicated to anybody who wants to hear it anywhere in all the wide world within a few minutes, or a few days, or at most a few months. In the agencies by which this is accomplished, rapid transit by ship, train or automobile, printing, photography, telegraph, and telephone, wired or wireless, chemistry plays an essential part, although it is so unpretentious a part that it rarely receives recognition. For instance, the expansion of literature and the spread of enlightenment, which put an end to the Dark Ages, is ascribed to the invention of movable type by Gutenberg, or somebody else, at the end of the four-

teenth century. But the credit belongs to the unknown chemist who invented the process of making paper. The ancient Romans stamped their bricks and lead pipes with type, but printing had to wait more than a thousand years for a supply of paper. Movable type is not the essential feature of printing, for most of the printing done nowadays is not from movable type, but from solid lines or pages. We could if necessary do away with type and press altogether, and use some photographic method of composition and reproduction, but we could not do without paper The invention of wood-pulp paper has done more for the expansion of literature than did the invention of rag paper 600 years ago.

Print is only an imperfect representation of the sound of speech, a particularly imperfect representation in the case of English because we can not tell how half the words sound from their spelling. But the phonograph gives us sounds directly, and the audion and the radio have extended the range of a speaker, until now a speaker may have an audience covering a continent and including generations yet unborn. What these inventions do for sound, photography has done for the sister sense of light. By means of them man is able to transcend the limitations of time and space. He can make himself seen and heard all round the earth and to all future years.

THE COST OF NIAGARA

If a man stood on the banks of the Mississippi at the time of the spring freshet, when the stream was carrying down to the Gulf fences, pigs, chickens, furniture and, occasionally, a house, he would be seriously concerned over the loss of the property of those who had so little to lose, and perhaps exert himself to save some of it; but the continuous calamity of Niagara arouses in him no feelings of a nature to mar his enjoyment. He shows the same æsthetic appreciation of a sublime and beautiful spectacle and the same indifference to its cost as Nero at the burning of Rome.

It is easier to comprehend how much it is costing us to keep up Niagara as a spectacle if we put the waste in concrete terms. Various engineers have estimated that it would be possible to get from Niagara Falls over 5,000,000 more horse-power than is now utilized. In one of the large steam plants of New York City the cost of power is $50 a year per horse-power. Taking these figures as sufficiently close for our purpose the water that goes over the Falls represents the annihilation of potential wealth at the rate of some $250,000,000 a year or nearly $30,000 an hour.

We are told that there are some millions of people in poverty and poorly nourished in this country, yet here is wasted the equivalent of 250,000 loaves of bread an hour. We may see with our mind's eye 600,000 nice fresh eggs dropping over the precipice every hour and making a gigantic omelet in the whirlpool. If calico were continuously pouring from the looms in a stream 4,000 feet wide like Niagara River it would represent the same destruction of property. If a Carnegie Library were held under the spout it would be filled with good books in an hour or two. Or we can imagine a big department store floating down from Lake Erie every day and smashing its varied contents on the rocks 160 feet below. That would be an exceedingly interesting and diverting spectacle, quite as attractive to the crowd as the present, and no more expensive to maintain. Yet some people might object to that on the ground of extravagance who now object to the utilization of the power of the falling water.

It must not be supposed that I am insensible to the beauties of nature or ignore their æsthetic and cultural

value. On the contrary, I would wish to enhance the interest and impressiveness of Niagara Falls by making it a rarer spectacle. The reason why people fail to appreciate the beauty of the clouds, of the sunset and of the landscape from their windows is because these are so common. If a bouquet of fireworks were shot off at eight o'clock every night we would not care to look at them. Of course the Falls would be turned on for all legal holidays and as often as there was sufficient demand for it. On such occasions those who wished to go down the current in barrels could enjoy their favorite sport. Weddings would naturally be arranged to come off at a time when the Falls fell. At the hours when the water was prohibited from making a run on the banks, rambles over the eroded rocks and worn channels would be of great interest to the geologist and the tourist. Couples and groups could be photographed at the Falls then, as they are now, by posing them in front of a painted screen.

Many more people would see Niagara and their enjoyment of it would be much greater if it could be seen only on fete days. Thinking they could see it any time, thousands of people have neglected it in favor of some passing show.

Of course, there is something impressive in the thought that the flood pours thundering into the abyss all of the time regardless of sight-seers. But if one has not sufficient imagination to find an equal emotional value in the contemplation of the varied life and industry it supports as it pours through the penstocks and spins the turbines he can swell with satisfaction on the thought of the thousands of years when it was of no use to anybody.

In 1893, when Lord Kelvin stood on the brink of Niagara, he was not so much impressed by its grandeur as he was saddened by the sight of such an enormous waste of power, and he expressed the hope that he would live to see it all utilized, an observation which was much ridiculed at the time by hard-hearted sentimentalists and unimaginative poets. To them Niagara was a mere spectacle, but to the great scientist, who had devoted his life to the study and exposition of the law of the conservation of energy, it was much more. His prophetic eye could see the poor who might be enriched, the homes that could be made happy, the hungry who might be fed, the naked who might be clothed, and the toiling millions who might be relieved of their burdens by the water dashing upon the rocks below for the amusement of idle tourists.

LOOK OUT FOR ALPHA CENTAURI

As if we did not have enough to worry about, what with winter coming on and coal so short and clothing so high, here comes along Professor Ellsworth Huntington, of Yale, with a book on "Climate Changes" which warns us that the stars in their courses may fight against us. He has a theory that the glacial epochs and the lesser disturbances of the earth's climate are largely due to prior disturbances in the sun's atmosphere and these in turn may be caused by the approach or increased activity of certain stars. All the stars, including our sun, are in radio communication with one another, and when one flares up over something it arouses responsible excitement in all the others within range. Then, too, the stars are not "fixed," as we used to think, but are wandering about in various directions, and when two stars come close enough together they become mutually inflamed by the proximity and may become permanently attached.

Now the nearest star to us is the brightest one in the Centaur constellation, therefore named Alpha Centauri. It is only about 25 trillion

Wide World Photos

THE ASTROPHYSICAL OBSERVATORY BUILT FOR PROFESSOR ALBERT EINSTEIN AT POTSDAM

miles away and its light takes four and a third years to reach us. Alpha Centauri is not only big and bright and relatively near, but it is triple and variable. Its two main components are like two suns the size of ours, revolving around one another every 81.2 years. When they are closest they are 1,100,000,000 miles apart and when their orbits separate most widely they are three times as far as that from each other. It is when the twin stars are nearest that we should expect them to be most active in sending out light waves and electrons. These reaching the sun might set up wild whirlings in the solar atmosphere, which would appear to us as an unusual abundance of sunspots, and would affect the weather on the earth.

The dates when the two bright spheres of Alpha Centauri were nearest together and most radiant are 81.2 years apart and these fall on the years 1388, 1469, 1550, 1631, 1713, 1794, 1875 and 1956. Comparing these with the records of sunspots, which have been kept only for the last century and a half, we see that such evidences of solar disturbances were most evident in periods ending in 1794 and 1875, and that another period of high solar activity started in 1914 and may be expected to end about 1956.

If this theory of stellar influence is true we may expect something to

happen somewhere between 1950 and 1956. What it will be Professor Huntington does not venture to surmise, but he reminds us that in the years preceding 1388, when Alpha Centauri was active, Europe was a very uncomfortable place to live in. There were droughts and floods, famines and freezings. The Baltic was frozen so that horse sleighs could cross from Germany to Sweden, and the Danube and the Rhine sometimes inundated the cities on their banks and sometimes nearly dried up.

There are more serious grounds for suspecting Alpha Centauri of a malign influence on the earth for that star was nearest to the earth 28,000 years ago, being then only 3.2 light-years away. Now this is the date that geologists have set for the end of the last Great Ice Age so the approach and proximity of Alpha Centauri may have had something to do with that spell of cold weather which came near freezing out the human race. The world is even yet convalescing from the chills of the Glacial Epoch. Greenland which once was really green with ferns and figs is still covered by an ice cap.

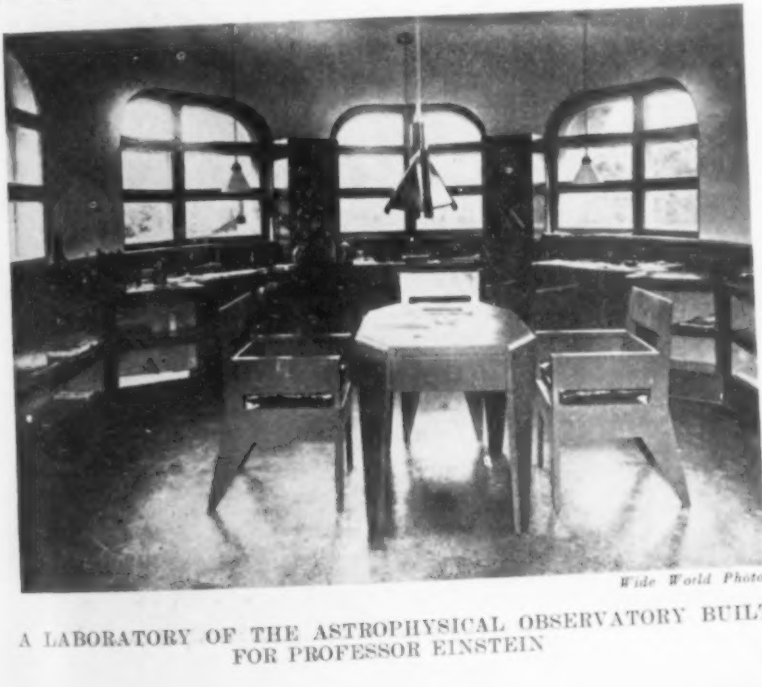
We need not fear another glacial age from the same cause for Alpha Centauri is now 4.3 light-years away and leaving us at the rate of thirteen miles a second. But Sirius is due in this vicinity in 65,000 years and that would be quite as—I should say, might be equally—bad for us.

But Professor Huntington endeavors to console us by reminding us that the human race not only survived several such periods of climatic stress, but has come out of them in each case stronger and better for the struggle for existence. He is a firm believer in the value of stormy weather. He is a New Englander.

NEW LIGHT ON THE ORIGIN OF LIFE

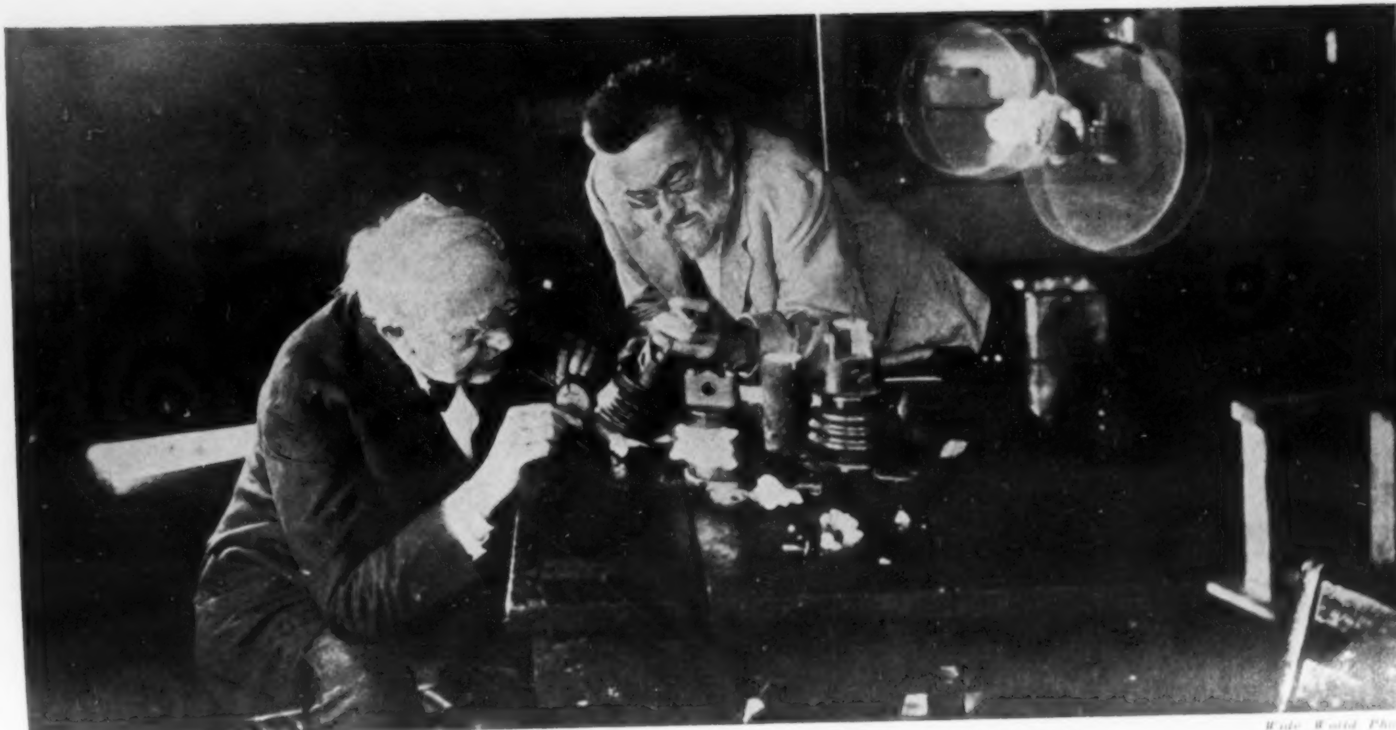
WAS the first living being a plant or animal? How could either originate out of non-existing matter?

These are questions that have hitherto baffled scientists. They could



Wide World Photos

A LABORATORY OF THE ASTROPHYSICAL OBSERVATORY BUILT FOR PROFESSOR EINSTEIN



Wide World Photos

MR. THOMAS A. EDISON AND DR. CHARLES P. STEINMETZ

In the Research Laboratories of the General Electric Company at Schenectady

trace back, more or less satisfactorily, the lines of development of plants and animals to the simplest and most primitive forms of life, but there they ran up against an insurmountable wall, on the near side of which was the world of living organisms and on the far side the world of inert mineral and inorganic matter.

We all know that non-living matter can be converted over into living matter for we do that ourselves whenever we eat or breathe. We all know that green plants have the power of building up sugar and starch and wood (the so-called carbohydrates) out of the water of the soil and carbon dioxide of the air, for we can see them do it any sunny day. But it is life only that can bring into the living organism this inorganic material. Water and carbon dioxide, plain "soda water," do not spontaneously change over into sugar or start to grow into a plant. It requires green colored granules of the leaves, called chlorophyll, to effect this transformation.

But chlorophyll is a very complicated chemical compound. It is formed only by green plants as they develop in the sun's rays from white sprouts. So the plant must exist before chlorophyll is formed. But, on the other hand, a plant could not exist unless it got its energy from the sugar and other stuff stored up previously by some chlorophyll-bearing plant. Even the simplest green plant can not live and grow on its nutritive salts in the sunshine unless it has a bit of plant-stuff to feed on as a starter.

We might surmise as a way out of the dilemma that animal life came first on the earth, and, in decaying, supplied the primitive plants with the necessary organic food stuff. But here we are blocked because animals are parasites of plants. They live on the sugars and so forth that the green leaves have stored up by means of sunshine.

So this was the perplexing situation. Plants can feed on animals or other plants. Animals can feed on plants or other animals. But where could the first animals or plants get their food when there was nothing but mineral matter in the world? It was worse than the old question, which came first, the hen or the egg?

But of late we are beginning to get light on the problem. The wall between the living and non-living is crumbling. Certain sugars and proteins, such as the plant forms that we eat, can now be made in the laboratory out of inorganic material. Artificial cells have been constructed that grow and crawl and feed themselves and stick out feelers and subdivide very much like living cells. It has been found that ultra-violet rays, that is, light of such short waves that it can not be seen, can convert water and carbon dioxide into sugar as chlorophyll does.

These short waves are not contained in the sunshine that reaches the earth to-day, but it is found that ordinary rays may act the same way in the presence of certain substances such as iron rust in water. These same energetic rays are able to incorporate the nitrogen of mineral salts into compounds like the protein of the living cell. So here we see the possibility that the action of the sunlight on the sea in primordial periods —or even in the present—might produce sufficient food to give a single cell a start in life and enable it to grow and multiply and develop into other and higher forms.

But how this primal cell got to going in this way the biologists are only beginning to surmise. Dr. E. J. Allen, at the recent Hull meeting of the British Association for the Advancement of Science, ventures the theory that the first organism was of the animal sort and spherical shape, but that it gradually grew a tail or whip that enabled it to rise to the sunny surface of the sea whenever it

sank below and that it there acquired the chlorophyll by which it could make its own food out of the air and water. This is far from knowing what did happen in those early days, but it is a great advance to be able even to speculate as to how it might have happened since not many years ago it seemed that it could not happen at all.

SCIENTIFIC ITEMS

We record with regret the death of Robert Wheeler Willson, emeritus professor of astronomy at Harvard University; of Guy Henry Cox, formerly professor of geology at the Missouri School of Mines; of Dr. Chauncey William Waggoner, head of the department of physics in West Virginia University; of F. T. Trouton, emeritus professor of physics in the University of London, and of E. Bergmann, director of the Chemisch-Technische Reichsanstalt, Berlin.

The Henry Jacob Bigelow medal of the Boston Surgical Society was presented to Dr. William W. Keen, of Philadelphia "for conspicuous contributions to the advancement of surgery," on the evening of October 25, when Dr. Keen addressed the society on "Sixty years of surgery, 1862-1922."

On the occasion of the celebration of the fiftieth anniversary of the Dutch Zoological Society there were admitted as honorary members: Professor O. Abel, Vienna; Professor M. Caullery, Paris; Professor L. Dollo, Brussels; Professor B. Grassi, Rome; Professor V. Häcker, Halle; Professor S. J. Hickson, Manchester; Professor N. Holmgren, Stockholm; Professor T. H. Morgan, New York; Dr. F. Sarasin, Basle, and Dr. J. Schmidt, Copenhagen.

Foster Hall, the chemical laboratory of the University of Buffalo, designed especially to meet the needs of the electro-chemical, hydro-electric, dye and steel industries on the Niagara frontier, was dedicated on October 27 in connection with the installation of Dr. Samuel P. Capen, of Washington, as chancellor of the university. Dr. Edgar F. Smith, president of the American Chemical Society, and Dr. Edwin E. Slosson, of Science Service, were speakers at the ceremony. The laboratory, erected at a cost of a million dollars, is the gift of O. E. Foster, of Buffalo.

In the will of Prince Albert of Monaco, who died on June 26 last, there are several gifts for scientific purposes. His farm at Sainte Suzanne is left to the French Academy of Agriculture, and the wish is expressed that the estate should remain a place for agricultural experiments, to demonstrate what science can obtain from sterile lands. Dr. Jules Richard will receive 600,000 francs to enable him to complete literary and scientific works in progress, including the results of the oceanographic cruises and the preparation of the Bathymetric Chart of the Oceans. The proceeds of the sale of the yacht *Hirondelle*, all books and publications of a scientific nature, as well as certain personal effects, will go to the Oceanographic Institutes at Paris and Monaco, while the Institute of Human Paleontology in Paris is to receive any personal effects relating to the work carried on there. The Paris Academy of Sciences will receive a million francs, the income of which is to provide a prize to be awarded every two years, the nature of the prize to be indicated by the academy, according to the needs of the moment; a like sum is bequeathed to the Academy of Medicine for a similar prize.

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